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MECHANICAL DEEP-PLACEMENT OF UREA FERTILIZER WITH A PRILLED UREA APPLICATOR SAVED FERTILIZER AND INCREASED YIELD FOR LONG DURATION WET LAND RICE VARIETY

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ABSTRACT

This experiment was conducted during the Boro season of 2016-2017 at Rajpat, Kashiyani to evaluate the performance of *BRRI Prilled Urea Applicator* (BPUA) and urea (N) fertilizer deep placement for long duration rice variety of BRRI dhan29. The treatments were T_1 = Urea deep placement by BPUA (70% urea fertilizer of recommended dose), T_2 = Urea deep placement by BPUA (80% urea fertilizer of recommended dose), T_3 = Hand broadcasting (Recommended dose of urea @ 270 kg ha^{-1}) and T_4 = Control (-N). Both actual and theoretical field capacity found less for operation of the machine at 20% saving of fertilizer due to frequent inputs of fertilizer in the hopper of the applicator. Field efficiency of the applicator was 59 and 53% for operation at 30 and 20% saving, respectively. Actual saving percentage of urea fertilizer was noted 34 and 24% in the field against the calibration of 30 and 20% of saving. From 45 to 105 days after transplanting, plant height did not vary with the mode and rate of urea fertilizer application. However, there was no significance difference of plant height and number of tillers between70 and 80% of recommended dose of urea fertilizer application in the non-oxidize zone by the BPUA. Deep placement of the urea fertilizer (70 and 80% of recommended dose) gave significantly higher yield (6.7-6.8 t/ha) compared to hand broadcasting of urea (6.1 t ha^{-1}). Straw yield did not vary with the mode and rate of fertilizer. Harvest index was also found similar irrespective of treatments. The agronomic efficiency and partial factor productivity for N observed higher in urea fertilizer deep placement field compared to broadcasting whereas both the parameters did not varied for 30 and 20% saving rate. However, panicles $hill^{-1}$ and filled grains per panicle did also not vary with the mode and rate of urea application while it was significantly higher than that of control. BPUA accounted the highest BCR (1.72 and 1.67) for 80 and 70% of the recommended urea fertilizer application in non-oxidized zone to the hand broadcasting of urea fertilizer (1.56). Farmer can apply 80% of urea fertilizer in non-oxidized zone by the BPUA for long duration rice variety.

Keywords: *Field capacity, applicator, deep placement of urea fertilizer, urea savings, grain yield*

INTRODUCTION

Urea is one of the major essential elements of plant. The plant takes fertilizer available in the root-zone as its food resulting increase yield. The ultimate aim of applying fertilizer to the root-zone is for the beneficial use of the plant. Farmers use fertilizer to increase the yield of crops. The prilled formed a smaller and softer substance than other materials commonly used in fertilizer blends. As a result, major portion of urea fertilizer lost in different ways after top application to the field. The nitrogen use efficiency from urea fertilizer is very low and the recovery of nitrogen in wetland rice seldom exceeds 40% (De Datta, 1989). Farmers in Bangladesh apply urea fertilizer in the rice field by hand broadcasting method. Its application efficiency is only 35 to 40%. Deep placement or subsurface placement of fertilizer also ensures better distribution in the root zone and prevent any loss by surface drain-off. Much effort has been made to improve fertilizer use efficiencies in low land rice production. Deep placement of urea fertilizer into the anaerobic soil zone is an effective method to reduce volatilization loss and increase the application efficiency up to 60 %. It has been proven that deep placement of urea (either granule or prilled form) in transplanted rice is an agronomically efficient and environmentally safe as compared with the traditional application method of prilled urea. Deep placement of urea could save 1.15 MT of fertilizer reduce the import burden when only 0.05 MT urea needs to be imported (BADC, 2011). If urea is applied into a desired depth, a huge amount of urea production could be reduced, which in turn would save a lot of natural gas. The saved natural gas could be used to generate electricity (Bowen *et. al*., 2005). Based on this concept, the scientists of Farm Machinery and Postharvest Technology Division of BRRI developed a prilled urea applicator title "BRRI Prilled Urea Applicator" to deep placement of prilled urea in between two rows of plants. Islam *et al.* (2016) conducted the field performance of BPUA to establish medium duration rice variety (cv. BRRI dhan28) in the farmer's field during Boro 2015. The authors stated that BPUA safely dispensed urea fertilizer in subsurface, increased the efficacy of urea fertilizer and saved 29-30% urea fertilizer without sacrificing grain yield. Islam *et al.* (2014, 2015, 2016, 2017) extensively tested the field performance of BPUA on BRRI dhan62 (short duration), BRRI dhan39 (medium duration: 135 days), in different locations of the farmer's field and got promising results on yield and yield contributing characters.

The advantage of the applicator is the savings of urea fertilizer and reduced the burden on foreign currency as government imported the fertilizer and supplied to farmer at subsidized price. It was found suitable during field trials in different soil conditions and seasons. Recommended fertilizer dose of different rice varieties (long and short duration) in different seasons is varied in wide range. The performance of BPUA was observed in different locations of Bangladesh under FMPHT division, BRRI for long duration rice variety (cv BRRI dhan29) by saving 30% urea, additional one top dress is required before panicle

initiation stage (Unpublished data). Therefore, BPUA should be recalibrated to apply urea fertilizer in different saving rate for long duration rice variety for identifying the suitable rate of deep placement. Furthermore, fertilizer use efficiency also needs to observe under different rate of application. Hence, an attempt has been undertaken to conduct the study on field evaluation the BPUA with the objectives of: (i) to calibrate and evaluate the applicator for the establishment of long duration rice variety (cv BRRI dhan29), and (ii) to observe the yield and yield contributing attributes.

MATERIALS AND METHODS

This study was conducted to evaluate the performance of BPUA in the farmer's field at Rajpat, Kashiyani, Gopalgonj, Bangladesh during the irrigated dry Boro season 2017. It is under Gopalganj-Khulna Bills under AEZ-14 (UNDP-FAO, 1988). Soil samples from the experimental field was collected and analyzed in the soil science laboratory, BRAC, Gazipur to identify the textural classes and fertility status (Table 1).

Table 1 Soil conditions of the experimental fields

Characteristics	Rajpat, Kashiyani, Gopalgonj
Soil texture	Silt loam
pH	7.80
Organic carbon in % (OC)	2.00
N (%)	0.17

Note: Soil of the experimental plots contained 23.74% sand, 22.6% clay and 53.66% silt

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 (70% urea fertilizer of the recommended dose) T_2 = Urea deep placement by BPUA (80% urea fertilizer of the recommended dose) T_3 = Hand broadcasting (Recommended urea fertilizer @ 270 kgha^{-1}) and T_4 = Control (no N). Seedbed was prepared by using spade and puddling was done after inundating the field. Puddled soil was leveled and raised to 5−10 cm height. Drainage canals were constructed for proper water removal. Sprouted seeds were broadcast in the seed bed in 25 December 2016.

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

Rice variety of BRRI dhan29 was taken as test crop to conduct the study. Forty two (42) days old seedlings were transplanted manually in the study field in 07 February 2017. Line-to-line and plant-to-plant spacing was maintained to 20 cm and obtained 25-26 hills m^{-2}. Three to four plants of seedling were transplanted in each hill.

Urea fertilizer was placed in non-oxidized zone after 2 days of transplanting by the BPUA. Before operation of the BPUA in the field, it was calibrated to maintain the pre-designed dose of fertilizer. BRRI recommended urea fertilizer dose was considered 270 kgha^{-1} (BRRI, 2016). At 70 and 80% of the recommended dose, the rate of urea fertilizer is 189 and 216 kgha^{-1} (Table 2). To maintain the desired rate of fertilizer, fertilizer dispensing rate per rotation of the driving wheel was calculated using the following formula. This formula was developed for easy calibration of the applicator.

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

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}

Table 2. Urea fertilizer rate of calibration

Method of application	Rate (Kg ha^{-1})	Dispensing rate (g/rotation)*
Hand broadcasting (three equal split)	270	-
Machine application (30% saving)	196	22.51
Machine application (20% saving)	216	24.80

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

Recommended dose of urea fertilizer (BRRI, 2016) was applied in the hand broadcasted plots (T_3) whereas 70 and 80% of the recommended dose in the machine application plots (T_1 and T_2, respectively). Triple super phosphate (TSP), muriate of potash (MoP), zinc sulphate ($ZnSO_4$) and gypsum fertilizer were applied at sowing. Urea fertilizer was broadcast in three equal splits at 7 days after transplanting, vegetative stage and before panicle initiation stage. The rate of fertilizer except urea was the same for all treatments (Table 3).

Table 3. Fertilizer application rate as basal and top dressing fertilizer

Basal dose (kg ha^{-1})				Dose Urea top dress (kg ha^{-1})*		
TSP	MoP	Gypsum	$Znso_4$	1st top dose	2nd top dose	2nd top dose
150	150	100	16	95	95	80

*Note: *Urea fertilizer top dressing only in T_3*

Performance of Applicator

Field capacity: Applicator operation time included time required during turning of the applicator, fertilizer refill time, operator's personal time, adjustment time etc. were summed to calculate the actual field capacity of BPUA, which is fertilizing area covered (ha) divided by the time of operation (hrs). Field efficiency was measured based on the

actual field capacity and calculated theoretical field capacity.

Actual saving percentage of fertilizer: Actual saving of fertilizer is varied from designed saving rate due to slippage, variation of wheel penetration, irregular speed of operation etc. Actual percentage of saving was calculated dividing the actual dispensing rate of fertilizer by the recommended rate of fertilizer of the respected area of operation.

Labor requirement

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

Operating cost of weeder

Operating cost (Tk hr^{-1}) of the applicator was calculated considering the fixed cost (Tk hr^{-1}) and variable cost (Tkhr^{-1}) using the method mentioned in Hunt (1995). 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 applicator (Tk)
S = salvage value (Tk)
L = working life of the applicator (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 purchasing price. Total fixed cost per year, FC = (a + b + c)

In variable cost calculation, the cost of 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) Lubrication oil cost per hr, O = 3 % of fuel cost
f) Repair and maintenance cost (Tk hr^{-1}), RPM = 3.5% of purchasing price (Tk yr^{-1}) * average annual use (hr yr^{-1}).

Total variable cost = (d + e + f)

Hand weeding was done at 20 and 45 days after transplanting (DAT) to keep the fields weed free. Only one application of Virtako (chlorantraniliprote 20 % + thiamethoxam 20 %) pesticide was applied to control stem borer infestation. Experimental plots were irrigated as and when needed.

Crops were harvested on 17 May, 2017 when 85-90% of the grains become golden. It was expressed as difference in grain yield between fertilized and unfertilized field divided by the quantity of nutrient apply (kgkg^{-1}).

$$AE = \frac{(G_f - G_u)}{N_a}$$

Where, G_f= Grain yield of the fertilized field (Kg ha^{-1})
G_u= Grain yield of the unfertilized field (Kg ha^{-1})
N_a = Quantity of N applied (Kg ha^{-1})

Partial factor productivity (PFP)

The grain yield per quantity of nutrient applied was considered as partial actor productivity (PFP). It was also expressed as kg kg^{-1}.

$$PFP = \frac{G_f}{N_a}$$

Data were analyzed as a single factorial design according to Gomez and Gomez (1984) using Statistix 10 program (Statistix 10 software, 2013). Means were compared with the least significant difference (LSD) test. Simple correlation analysis was carried out with Excel 2010 to determine the relationship of grain yield to yield attributes.

RESULTS AND DISCUSSIONS

Effects of urea fertilizer application method and rate on plant growth yield and cost characteristics of rice cultivation have been presented in tabular and graphical format.

MACHINE PERFORMANCE

Field capacity of BPUA

Field capacity of BPUA varied with the rate of fertilizer saving percentage. Actual field capacity was found 0.12 and 0.11 hah^{-1} for operation of the machine at 30 and 20% saving of fertilizer (Table 4). Both actual and theoretical field capacity was observed less for operation of the machine at 20% saving of fertilizer due to frequent inputs of fertilizer in the hopper of the applicator. Islam *et al.* (2015) obtained the field capacity of BPUA was 0.09-0.10 ha hr^{-1}. Hossen *et al*. (2013) found similar field capacity of the manual operated BRRI USG applicator.

Field efficiency of the machine was found 59 and 53% in calculation for operation at 30 and 20% saving. It was varied with the field size and shape, length of the field, number of turn, forward speed etc (Hossen, 2016). There were minimum field efficiency of the machine were observed due to small area and frequent turning of the machine. The field efficiency of BPUA was obtained 64-65% in two locations in the farmer's field (Islam *et al.* 2015).

Theoretical and actual saving of urea fertilizer by the machine

Before field operation of the machine, it was calibrated to save 30 and 20% of fertilizer from recommended dose. In the field, saving percentage was observed 34 and 24% against the calibration of 30 and 20% of urea saving (Table 5). It might be due to variation of operational speed, more penetration of the driving wheel in the field during operation etc.

Table 4. Field performance of the BPUA

Condition of BPUA operation	Forward speed of operation (km hr^{-1})	Actual field capacity (ha hr^{-1})	Theoretical field capacity (ha hr^{-1})	Field efficiency (%)
Machine application (30% saving)	2.46	0.12	0.20	59
Machine application (20% saving)	2.61	0.11	0.21	53

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

Table 5. Percent of fertilizer saving as affected by two saving mood of operation

Condition of BPUA operation	Area (m^2)	Urea dispensed (kg)	Urea dispensed rate (kg ha^{-1})	Theoretical rate of dispensed (kg ha^{-1})	Recommended dose (kg ha^{-1})	% of saving	% of deviation (±)
Machine application (30% saving)	243.8	4.33	177.60	196.00	270.00	34.22	+4.22
Machine application (20% saving)	260.5	5.37	206.01	216.00	270.00	23.70	+3.70

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

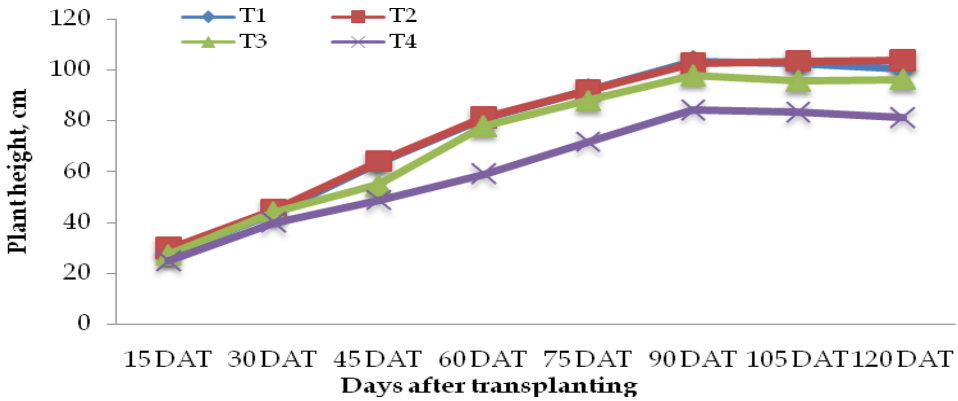

Fig. 1 Plant height with respect to days after transplanting as affected by rate and application methods of urea fertilizer

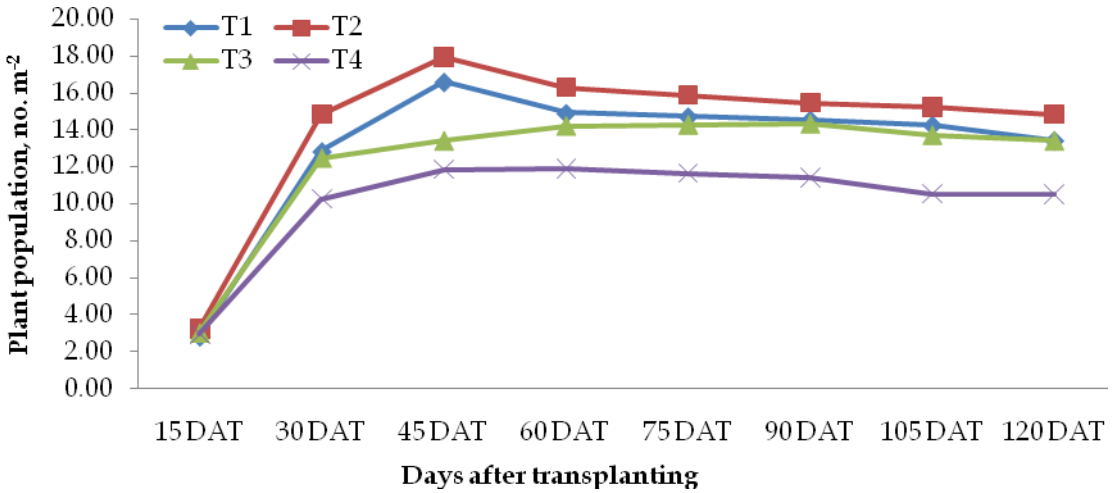

Fig. 2 Plant population with respect of date after transplanting as affected by rate and application methods of urea fertilizer

CROP PERFORMANCE

Plant height

Plant height with different date of transplanting is shown in figure 1. It was not varied up to 30 days after transplanting. Significant variation of plant height was observed from 45 days after transplanting to the harvest. From 45 to 105 days after transplanting, significantly lower height of the plant was observed in control plot whereas plant height for urea deep placement either 70% or 80% of the recommended dose and hand broadcasting was found similar. In 120 days after transplanting, urea deep placement (both 80 and 70%) showed significantly higher plant height compare to hand broadcasting method of urea application. There was no significance difference between 80 and 70% of recommended dose of urea fertilizer application in non-oxidize zone by the BPUA.

Number of tiller

Number of tillers hill^{-1} with different date of transplanting is shown in figure 2. It was not varied up to 30 days after transplanting whereas variation of tiller number per hill was observed at 45 DAT. Significant variation of tiller number was observed from 75 days after transplanting to the harvest. From 75 to 105 days after transplanting, significantly lower tiller number of the plant was observed in control plot whereas tiller number per hill for urea deep placement either 70% or 80% of the recommended dose and hand broadcasting was found similar. There was no significance difference of tiller number per hill between 80 and 70% of recommended dose of urea fertilizer application in non-oxidize zone by the BPUA.

Yield Performance

Grain and straw yield varied with the mode and rate of urea fertilizer application (Table 4). Deep placement urea fertilizer (70 and 80% of recommended dose) gave significantly higher yield compared to hand broadcasting of urea. Straw yield did not vary with the mode and rate of fertilizer. However, harvest index was also fund insignificant irrespective of treatments. Deep placement of urea fertilizer as briquette form also gave higher yield compared to hand broadcasting method (Hossen, 2013).

Table 4. Yield performance as affected by mode and rate of urea fertilizer application

Treatments	Grain yield at 14% m.c	Straw yield (tha-1)	Biological yield (tha-1)	% of HI
T1	6.7	5.2	11.9	56.5
T2	6.8	6.0	12.8	53.3
T3	6.1	6.3	12.3	49.8
T4	3.3	3.1	6.5	51.3
CV, %	3.4	12.3	6.3	4.9
LSD	0.4	1.3	1.4	NS

Note: T_1 = Urea deep placement by BPUA (70% Urea), T_2 = Urea deep placement by BPUA (80% Urea), T_3 = Hand broadcasting (Urea @ 270 kg ha^{-1}) and T_4 = Control (-N).

Yield contributing parameters

Yield contributing parameters influenced the grain yield directly. Hills per unit area and 1000 grain weight did not vary significantly. However, panicles per hill and filled grains per panicle did also not vary significantly with the mood and rate of urea application while it was significantly higher than that of control (Table 5).

Table 5. Yield contributing parameters as affected by mode and rate of urea fertilizer application

Treatments	Hills m^{-2}	Panicles hill^{-1}	Filled grains panicle^{-1}	1000-grain wt.@14% (g)
T_1	27.8	12.2	91.3	22.2
T_2	26.3	13.6	90.7	21.4
T_3	27.0	12.3	88.2	20.8
T_4	26.9	9.4	64.2	20.8
CV, %	6.60	6.50	6.20	3.40
$LSD_{0.05}$	NS	1.5	10.38	NS

Note: T_1 = Urea deep placement by BPUA (70% Urea), T_2 = Urea deep placement by BPUA (80% Urea), T_3 = Hand broadcasting (Urea @ 270 kg ha^{-1}) and T_4 = Control (-N).

Agronomic use efficiency for N

The agronomic efficiency for N application method and rate was found significant ($P < 0.01$). The AUE observed higher in urea fertilizer deep placement field (35-37 kg kg^{-1}) compared to broadcasting (22 kg kg^{-1}). Contrary to, deep placement of urea fertilizer did not varied for 30 and 20% saving rate (Table 6). Khatun *et al.* (2015) was found 42 AUE at BRRI research field, Gazipur for 30% saving of urea fertilizer at non-oxidized zone. In BRRI dhan29, AUE varied from 5.9 to 30.4 kg kg^{-1} (Khatun, 2015).

Partial Factor Productivity (PFP)

The partial factor productivity (PFP) for N application method and rate was also found significant. The PFP observed higher in urea fertilizer deep placement field (74-68 kg kg^{-1}) compared to broadcasting (49 kg kg^{-1}). Contrary to, deep placement of urea fertilizer did not varied for 30 and 20% saving rate (Table 8). Khatun *et al.* (2015) was found 82 kg kg^{-1} for N at BRRI research field, Gazipur for 30% saving of urea fertilizer at non-oxidized zone. In BRRI dhan29, PFP varied from 22-91 kg kg^{-1} (Khatun, 2015).

Table 6. Effect of N application methods and rate on crop parameters

Treatments	AUE (Kg grain KgN^{-1})	PFP (Kg grain KgN^{-1})
T1	37.3	74.3
T2	34.6	68.1
T3	22.0	48.8
T4	-	
CV, %	4.82	2.37
$LSD_{0.05}$	4.82	**2.27**

Note: T_1 = Urea deep placement by BPUA (70% Urea), T_2 = Urea deep placement by BPUA (80% Urea), T_3 = Hand broadcasting (Urea @ 270 kg ha^{-1}) and T_4 = Control (-N).

Economic performance

Economic analysis including cost of production and return is presented in Table 7. BPUA accounted the highest BCR (1.72 and 1.67) for 80 and 70% of the recommended urea fertilizer application in non-oxidize zone hand broadcasting of urea fertilizer (1.56).

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	84315	141800	57485	1.68
T2	84813	145000	60187	1.71
T3	85169	131450	46281	1.54
T4	78864	70650	-8214	0.90

Note: T_1 = Urea deep placement by BPUA (70% Urea), T_2 = Urea deep placement by BPUA (80% Urea), T_3 = Hand broadcasting (Urea @ 270 kg ha^{-1}) and T_4 = Control (-N).

CONCLUSION

Field performance of the BPUA was found suitable under the both 70 and 80% of urea deep placement in operation though field capacity was found more for 70% rate of fertilizer application. Grain and straw yield did not vary

with the two different rate of application while benefit-cost ratio (BCR) was found more for 80% of urea fertilizer application in non-oxidize zone. Farmer can apply 80% of urea BPUA for long duration rice variety (cv. BRRI dhan29). This study needs to be conducted in different soil condition and cropping pattern.

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