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An Environment-friendly Technology for Enhancing Yield and Nitrogen Use Efficiency

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FOREWORD

Rapid increase in fertilizer prices in recent years along with low nitrogen recovery by low-land rice has impelled a re-inspection of urea briquetting technology. The small and marginal farmers who constitute the backbone of rice farming in India and other Asian countries face problems caused by loss of precious fertilizer nitrogen. ICAR-National Rice Research Institute, Cuttack, Odisha, India attempted to develop technologies to increase nitrogen use efficiency in rice. Urea briquette management makes nitrogen fertilizer use agronomically more efficient, economically more attractive with less risk and reduced losses to the environment compared to conventional urea.

The bulletin entitled "Placement of Urea Briquettes in Lowland Rice: An Environment-friendly Technology for Enhancing Yield and Nitrogen Use Efficiency" is an attempt to provide a holistic information to its readers with a broad overview of urea briquette and its application, protocol for briquette preparation, testing of performance of urea briquette, chemistry of briquette formulation, machines and instruments for precise urea briquette application, environmental friendliness of this technology and farmers field demonstration.

I appreciate the efforts of the authors in bringing out this bulletin and do hope that farmers, researcher, planners and extension agents will find this publication useful.

Place: Cuttack
April, 2017

(H. PATHAK)
Director, NRRI

PREFACE

Rice is one of the major food crop in Southeast Asia. To meet the global food requirement 1.2-2.4% increment in rice production is required. To produce one kg of rice grain it needs 15–20 g nitrogen (N) application. Enhancing N application may increase the yield but it caused environmental pollution. Despite the tremendous amount of research, fertilizer N use efficiency of lowland rice is relatively low due to loss of applied N through leaching, volatilization and denitrification more particularly when it is broadcasted in flooded rice soils.

Urea is one of the most widely used N fertilizers in rice because of its high N content, low cost and favorable physical properties. However, the major problem associated with urea is that upon broadcasted in the rice field, it is rapidly hydrolyzed producing NH_4^+ which is quickly transformed to NO_3^- by the process of nitrification in the aerobic zone. Having larger surface area, the use of prilled urea (PU) results in loss of 55–70% applied N and sink into the air or water. Hence, there is an option of deep placement of larger size urea which not only enhances its use efficiency but also delivers an environmental benefit by reducing runoff and volatilization losses of nitrogen.

Various types of deep placement or slow release form (e.g. supergranules, mudballs, briquettes, coated urea) were tested to increase N use efficiency. Urea briquette mixed with low-cost filler material and binding agents were prepared. For effective placement of urea briquettes single row, two row, three row, injector type, and top dressing mechanical type applicators were developed in our institute.

This bulletin gives a complete package of practices on urea briquette preparation with suitable filler material and binding agents, performance results of urea briquette in lowland rice, and applicators suitable for urea briquette placement. We hope that this bulletin will act as a useful tool for rice researchers, extension workers, students, and farmers, and would help to boost up the rice production with minimum input.

Authors

CONTENTS

1. Introduction

Nitrogen is one of the most limiting nutrients for lowland rice production. Despite the tremendous amount of research, fertilizer N use efficiency of lowland rice is relatively low due to loss of applied N through leaching, volatilization and denitrification more particularly when it is broadcasted in flooded rice soils. The unique environment of flooded lowland rice soil, which is characterized by the presence of thin oxidized layer overlying reduced zone, facilitates simultaneous occurrence of both aerobic and anaerobic N transformation processes enabling loss of N from the system in various forms. Urea is one of the most widely used N fertilizers in rice because of its high N content, low cost and favourable physical properties. However, the major problem associated with urea is that upon broadcasted in the rice field, it is rapidly hydrolyzed producing NH_4^+ which is quickly transformed to NO_3^- by the process of nitrification in the aerobic zone. The NO_3^- ion is transported to the underlying reduced zone where it becomes substrate for denitrification process. The presence of aerobic and anaerobic zone in close vicinity thus couples nitrification with denitrification and accelerates the process of N loss from the system as N_2 and N_2O. Additionally, in flooded lowland rice soil high NH_4^+-N level and increased pH of floodwater resulted from rapid hydrolysis of urea cause a considerable amount of N loss as NH_3 through volatilization. Therefore, depending upon the season, yield level, and the rate and timing of N application the recovery efficiencies for lowland rice in the tropics typically varied from 30 –50% of applied N (Frageria and Baligar 2001). The flow of reactive N from the rice ecosystem to environment has severe economic and environmental repercussions in terms of fossil fuel burning, ground water pollution and global warming. The N_2O is a potent greenhouse gas having global warming potential 310 times more than the CO_2. Improving nitrogen use efficiency of lowland rice and minimizing nitrogen losses is, therefore, a priority area of research to prevent environment pollution and saving in the fertilizer cost to the farmers.

One of the important strategies to reduce N loss from urea is to slow down the process of conversion of urea to NH_4^+ and subsequently to NO_3^-. A number of urease and nitrification inhibitors have been developed and used for this purpose, but because of their high cost and other specific problems associated with them, these compounds are not popular among the farmers of India. Another approach for regulating the release of N from urea is the use of urea supergranules (USGs) which are large (1 to 2 g) particles of ordinary urea containing 46% N in amide form. The USG acts as a slowly available N fertilizer as a result of diffusive transport and cation exchange which control the rate and duration of availability of USG-N to the rice plants (Savant and Stangel1990). The efficiency of USGs is increased by placing these granules 5-7 cm below surface layer manually or with the help of an applicator. Deep placement of USGs at reduced zone prevents the fast conversion of NH_4 to NO_3 and subsequent losses. Therefore, N availability to the plant lasts for a longer period than the traditional urea fertilizer, which results in significant increases in N uptake and grain yield.

2. Urea supergranules/urea briquettes/urea pellets

Several attempts have been made by the scientists to develop and evaluate the deep placement of urea supergranules in lowland rice (De Datta 1989, Mohanty et al., 1999). Urea supergranules are generally prepared by melt granulation or by mechanical compaction and contain 46% N as NH_2 (amide form). Urea pellets/briquettes are oval shaped supergranules of urea having weight of 1-2 g prepared by compaction using briquette/pellet making machine. Studies showed depending on agro-climate and N rates used, in general deep-placed USG could save up to 65% of urea fertilizer and increase grain yields up to 50% over that with the same amount of split-applied N as prilled urea (PU), especially in the lower range of N rates (Savant and Strangel, 1990). Laboratory studies showed ammonia volatilization was reduced to 3.3 percent when urea supergranules (USG) were used (Sudhakar and Prasad, 1986). In a two-year field study with direct seeded rice (drilled in moist bed), Thomas and Prasad (1987) observed that in terms of yield and N uptake the performance of urea supergranules and urea briquettes were superior to sulphur coated urea, neem cake coated urea and prilled urea. The increases in grain yield following deep placement with USG were 8 to 18% relative to broadcasting method with PU (Bandaogo, 2014). Urea supergranules inhibited nitrification up to seven weeks and reduced both NH_3 and NO_x emissions up to 94%, compared to urea (Khalil, 2011). With technical assistance from International Fertilizer Development Center (IFDC), urea supergranule technology has been widely tested and promoted in different parts South Asia, more particularly in Bangladesh where this is popularly known as Guti urea technology (plate 1 & 2). A study says cultivated lands using Guti urea get three times better result than the lands cultivated by urea sprayed by hand in the traditional method and earn good amount of profit (Sikder and Jian, 2014).

Plate 1. Urea briquette making machine

Plate 2. Oval shaped supergranules (urea pellets/ briquettes) prepared by mechanical compaction using briquette/pellet making machine.

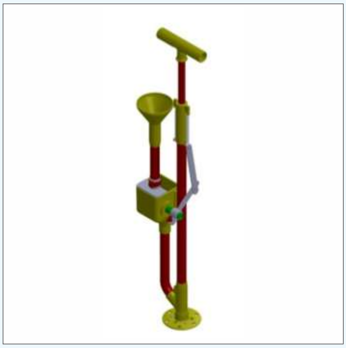
Though the agronomic superiority of the deep placement of USG *vis-a-vis* split applications of PU in transplanted rice have been demonstrated through several field experiments, this technology could not become popular among the rice growers due to several reasons. Difficult and time-consuming application method, high labour cost and non-availability of user-friendly urea deep placement applicator are the major bottlenecks that prevent its wide scale use by small and marginal farmers of eastern India. Apart from that, this practice is not suitable for highly permeable soil with coarse texture and low cation exchange capacity (CEC) because the high leaching loss of N from USG may reduce its uptake by crop.

3. Application of urea briquettes

Urea briquettes/pellets are generally placed manually at 7-10 cm soil depth at the rate of one USG near the centre of each four rice hills as per the IFDC guideline. Though the manual method is an efficient method of urea deep placement, the associated high labour cost and drudgery often discourage farmers from adopting this practice. Several attempts have been made in the past to develop continuous operation type and non-continuous injector type applicators for deep placement of urea briquettes in transplanted rice. The continuous operation-type applicators were found to be labour saving but several designs related problems with respect to metering and depth of placement make these applicators less efficient than the manual placement. The non-continuous injector type urea briquette applicators are generally less labour saving as compared to continuous operation-type applicators. The IFDC developed a non-continuous injector type urea briquette applicators made of polyvinyl chloride (PVC) pipe which is simple to use, lightweight and affordable (plate 3). But this type of applicator many times poses operational difficulties due to clogging of injector mouth with soil often which prevents the smooth release of briquettes into soil. Till date, an applicator that is easy to use, affordable and efficient for deep placement of urea

Manually operated push type continuous operation two-row USG applicator developed by Bangladesh Agricultural Research Institute (BARI)

Motor operated USG applicator developed by Bangladesh Agricultural University



Non-continuous injector type urea briquette applicators made of polyvinyl chloride (PVC) pipe developed by IFDC

Plate 3. Manual and motor operated continuous and non-continuous type urea briquette applicators

briquettes in rice fields of varying soil condition is not available. Therefore, research is required to develop and standardize user-friendly, cost effective agronomically efficient applicators for deep placement of urea briquettes/pellets for different rice growing regions according to the type of soil, variety and crop growth stage. In addition to this the usefulness and efficiency of briquettes also depend upon several other factors *viz*. strength and durability of briquette to enable it to be applied through applicators without breakage, concentration of urea in the briquette to ensure uniform distribution of N to crops without any burning injury and rate of release of N to meet the timely requirement of crop.

4. Protocol of briquette preparation

4.1 Oil as binding and nitrification inhibiting agents

Urea briquettes were prepared at NRRI by mechanical compaction method using a urea briquetting machine (plate 4). To improve the strength of briquettes and reduce the breakability, urea was mixed thoroughly with oils of *neem (Azadirachta indica)* and *karanj (Pongamia pinnata)* at a rate of 40 ml oil per 1 kg urea before compaction (plate 5). Apart from being good binding agent the oils used, contain active ingredients that reportedly inhibit nitrification activity in soil. Mixing oil reduced the breaking percentage to 2-5 % as compared to 25 - 30 % in urea pellets without a binding agent.

Plate 4. Urea briquettes/urea pellets prepared from granular urea in briquette/pellet making machine (breaking 25-30%)

Plate 5. Urea briquettes/urea pellets prepared after mixing granular urea with oil (breaking 2-5%)

4.2 Use of low-cost filler and binding agents

Several materials like phospho-gypsum, fly ash, silica powder, neem cake and rice husk were used as an amendment. A commercially available biodegradable and water soluble binder was used to bind those amendments with urea. The proportion of urea, amendments and binder used to prepare the agglomerated briquettes is given in table 1.

Table 1 Proportions of amendments, prilled urea and binder in urea briquettes

Code	Amendments	Proportion (prilled urea: filler material)	Binder (% of solid material)
UPGB	Phospho-gypsum	1:1	10
UFAB	Fly ash	1:1	10
USPB	Silica powder	1:1	15
UNKB	Neem cake	1:1	15
URHB	Rice husk	1:1	15

Urea fertilizer and amendment were taken in a tray in specified proportion; binder was added at the rate of 10 - 15% of total solid material (plate 6a). Materials were mixed thoroughly kept for one hour before preparing briquette. In case of urea+ rice husk mixture materials were kept for one day after addition of binder. The urea briquettes were prepared in a small urea briquette making machine by roll pressing process using indented pocketed rolls (plate 6b, Lupin et al., 1983).

Plate 6 a) Addition and mixing of filler material and binder to prilled urea

Plate 6 b) Preparation of urea briquettes in briquette making machine

The breakage percentage while preparing different briquettes (plate 7) were as follows, urea briquette (UB): 10%, UPGB: 22%, UFAB: 16%, USPB: 35%, UNKB: 50%, URHB: 55%.

Plate 7. Urea briquette prepared with different filler material

Characteristics of five products including their weight, urea content and time taken for dissolution are presented in Table 2.

Table 2 Weight, urea content and time taken for dissolution/disintegration of briquettes in distilled water

Code	Weight (g)	Urea content (g)	Time taken for dissolution/disintegration
UB	1.00	0.46	10 minutes
UPGB	1.41	0.63	3 minute 45 second
UFAB	1.08	0.49	24 hour
USPB	1.20	0.51	1 hour
UNKB	0.96	0.40	3 minute 5 seconds
URHB	0.98	0.42	2 minute 4 second

5. Testing performance of urea briquettes in lowland rice

5.1 Neem and karanj oil based briquettes

The field trials were conducted during dry and wet seasons of year 2014 with variety Naveen and Gayatri, respectively to evaluate the performance of deep placement of urea briquettes prepared by mixing urea with neem and karanj oil. Six treatments including T1: no nitrogen; T2: plain urea granule; T3: neem coated urea; T4: urea briquette; T5: urea + neem oil briquette; T6: urea + karanj oil briquette was replicated four times in a randomized block design. Recommended dose of N (100 kg ha^{-1} in dry season and 80 kg ha^{-1} in wet season) was applied in three splits i.e. 50% basal, 25% at maximum tillering and 25% at panicle initiation. Urea briquettes were deep placed manually at a depth of 5-7 cm. Phosphorus and potassium were applied as per recommendation as basal at the time of transplanting. Emission of N_2O from soil during dry season of 2014 was measured following standard protocol (Bhattacharyya et al., 2013) that involves gas sampling by manually closed chamber method followed by analysis in a gas chromatograph attached with electron capture detector (ECD). The crop was harvested at maturity, observations on grain and straw yield were recorded, grain and straw samples were analysed for N content to estimate N uptake and N use efficiencies (table 3).

Table 3 Yield, agronomic N use efficiency (AE_N), N uptake and N recovery efficiency (RE_N) of transplanted rice with deep placement of urea briquettes

Treatments	Yield (t ha^{-1})		AE_N (kg kg^{-1})		N uptake (kg ha^{-1})		RE_N (%)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
T1	3.0 d	3.1 d	-	-	48.9 d	45.8 d	-	-
T2	4.5 c	4.1 c	14.9 b	13.1 c	77.6 c	67.2 c	29.4 c	26.8 c
T3	4.9 b	4.6 b	18.0 b	18.5 b	84.5 b	76.0 b	35.5 b	37.8 b
T4	5.4 a	5.0 a	23.7 a	23.6 a	96.1 a	83.0 a	47.2 a	46.5 a
T5	5.6 a	5.0 a	25.6 a	24.2 a	95.3 a	82.5 a	46.4 a	45.9 a
T6	5.5 a	5.0 a	24.5 a	23.8 a	92.8 a	84.9 a	43.9 a	48.9 a
L.S.D. ($P \leq 0.05$)	0.4	0.35	3.1	4.0	5.9	6.0	5.8	7.8

Results revealed that the N_2O-N emission and global warming potential per unit yield expressed kg CO_2 equivalent t^{-1} under urea briquettes were significantly lower than plain urea granule and neem coated urea (Figure 1). Deep placement urea briquettes (T4, T5 and T6) resulted in 16.8-19.7 and 8.2-12.6 % higher grain yield as compared to plain urea granule and neem coated urea respectively, during both the season. Significantly higher N uptake, AEN, REN were also recorded with the application of urea briquettes.

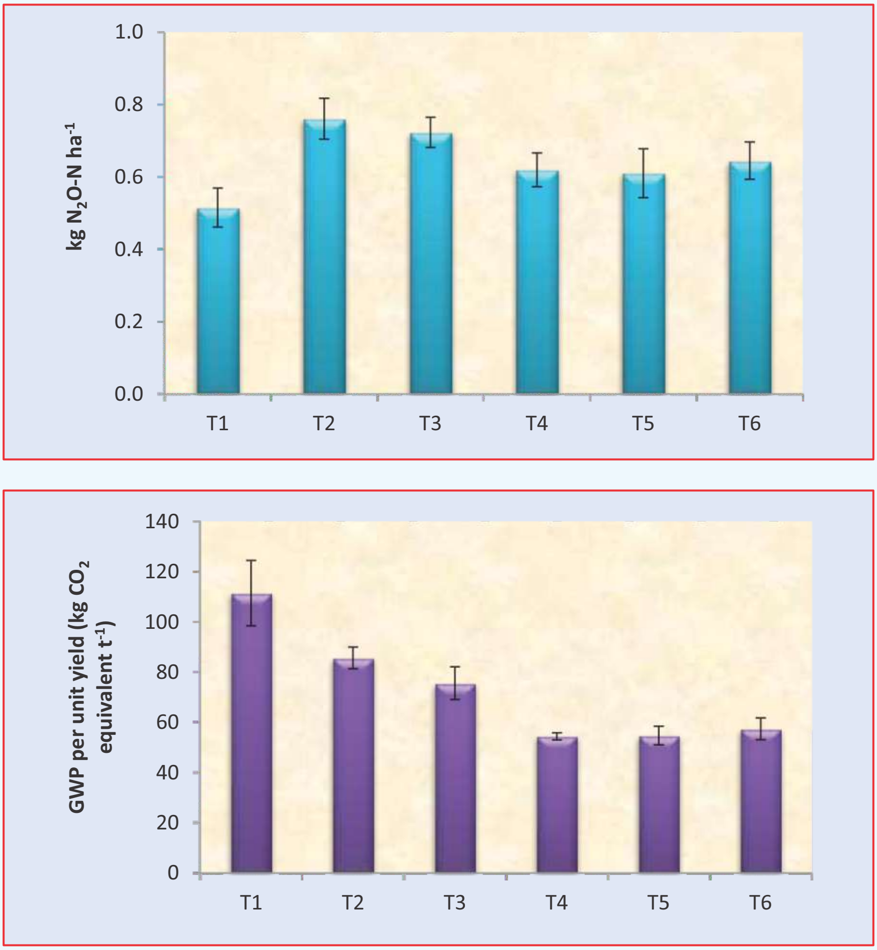


Figure 1. Emission of N_2O-N and GWP per unit yield under different treatments

5.2 Agglomerated urea briquettes with different filler material

Suitable amendments viz. phospho-gypsum, fly ash, silica powder, neem cake and rice husk as filling materials and biodegradable binding agents to prepare agglomerated urea briquettes from prilled urea by mechanical compaction method using a urea briquette machine.

Phospho-gypsum, a by-product of the phosphatic fertilizer industry is a moderately soluble source of calcium and sulphur, two nutrients essential for plant growth. Vasistha et al. (2010) observed coating of urea with phospho-gypsum enhanced crushing strength and reduced dissolution rate of urea. Studies showed phospho-gypsum coated urea increased the yield of aromatic rice cultivar *'Pusa Sugandh 5'* (Pusa 2511) compared to prilled urea and increased the efficiency of prilled urea (Shivay et al., 2015). Phospho-gypsum reported to reduce N_2O emission by affecting the nitrification process (Luo et al., 2013). Fly ash, a by-product of coal combustion, emitted by coal-based power plants has been reported content several elements which help in reclamation of acidic soil and also improves soil properties for plant growth. Silica powder (SiO_2) often used as filler material in cement concrete for higher compressive strength. In addition to this, it is also a source of silica, a beneficial element for the growth of rice. *Neem* cake has been found as an effective nitrification inhibitor (Prasad and Power, 1995; Parmar and Singh, 1993). *Nimin* (an alcohol extract of *neem*) has been reported to increase N use efficiency (Usha Kiran and Patra, 2003). Use of amendments and binders improved the crushing strength of briquettes. Additionally, amendments acted as filler material and reduced the concentration of urea in pellet which will ensure its uniform distribution in the field.

6. Dissolution and hydrolysis of urea in urea briquettes

Buried bag method was used to study dissolution and subsequent hydrolysis of urea in urea briquettes (plate 8). Briquettes that contain 9000 mg urea each was taken in small perforated bags/pouches (10 cm×10 cm) made up of degradable material. The dissolved urea could pass through the perforations without any end product inhibition of urea dissolution. Soil to moisture ratio of 1:1 was maintained throughout the study period. The bags containing urea pellets were placed at a depth of 2 cm in soil contained in the plastic pots. The destructive sampling was done periodically at different time intervals (6 h, 12 h, 24 h, 48 h and 72 h) after incubation.

Plate 8. Buried bag technique to study urea hydrolysis

In all the treatments 93-96% of urea dissolved within six hour. The dissolution rate was faster in urea pellet followed by USPB, UNKB, UFAB and UPGB. At the end of incubation after 72 hours, the highest concentration 132 mg was observed in UPGB and the lowest concentration 7.62 mg was in urea pellet (Figure 2a). After six hours of incubation highest inorganic N (NH_4-N+ NO_3-N) concentration was seen in urea pellet (245 mg kg^{-1}) and lowest in UPGB (133 mg kg^{-1}). For the most part of the incubation period, UPGB and USPB maintained lower NH_4-N+ NO_3-N concentrations than the other treatments. However, after 72 hours of incubation, the concentration was highest in UPGB (951 mg kg^{-1}) followed by UFAB (851 mg kg^{-1}) (Figure 2b).

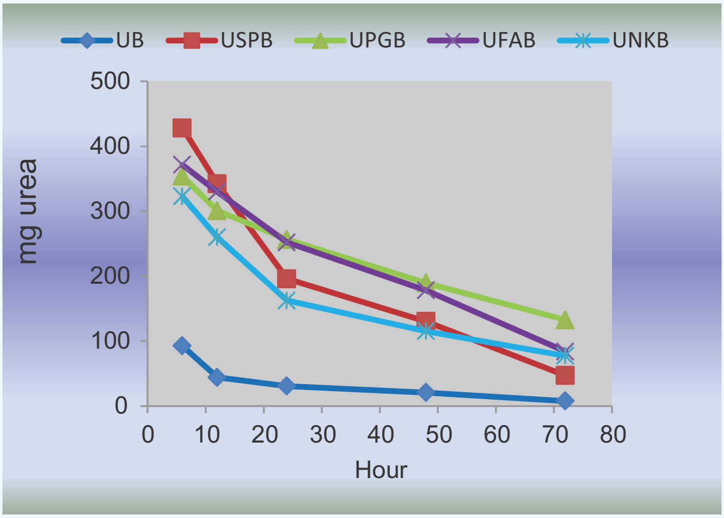


Figure 2a. Quantity of urea left in the bags during sampling event

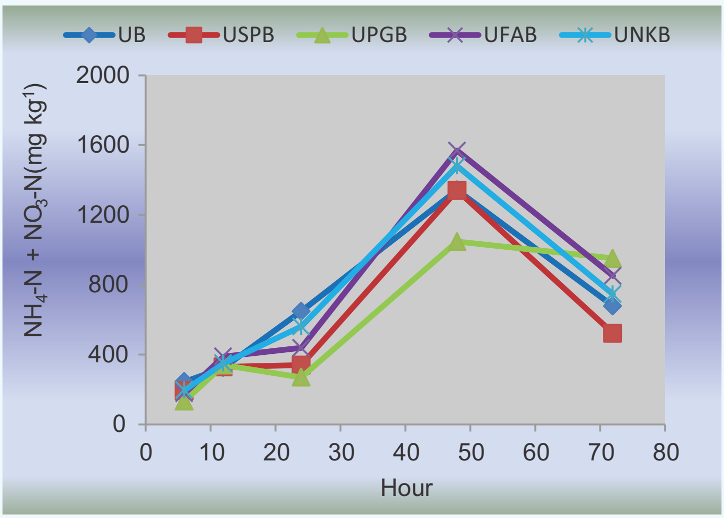


Figure 2b. Concentration of total inorganic N (NH_4-N + NO_3-N) in soil during sampling event

7. Field trial to evaluate agglomerated urea briquettes in transplanted rice

A field experiment was conducted with rice cultivar Naveen during the dry season of 2015 with eight different treatments- *viz.* no nitrogen (T1), urea granule (T2), UPGB (T3), UFAB (T4), USPB (T5) UNKB (T6), URHB (T7) and UB (T8). All the treatments were replicated thrice in randomized block design. Nitrogen, phosphorous and potassium were applied to all the plots at rates of 100 kg N ha^{-1}, 40 kg P_2O5 ha^{-1} and 40 kg K_2O ha^{-1}, respectively. Phosphorus and potassium were applied as basal; nitrogen was applied in three splits *i.e.* 50% basal, 25% at maximum tillering and 25% at panicle initiation. Urea briquettes were deep placed manually at a depth of 5-7 cm. Biomass yield and yield parameters were recorded after harvest of the crop. The nitrogen content of grain and straw samples were analyzed to determine N uptake and N use efficiency. Emission of N_2O was measured using manual chamber method of gas sampling (Bhattacharyya et al., 2013) followed by analysis in gaschromatography (Chemito CERES 800 PLUS, M/s Thermo Scientific) equipped with electron capture detector.

The highest yield, N uptake, AE_N, and RE_N were observed in UFAB followed by UPGB. Deep placement of briquettes except URHB resulted in lower N_2O emission as compared to the broadcasting of urea granule. The lowest GWP per unit yield was recorded in UFAB followed by UPGB and UB (Table 4).

Table 4 Yield, nitrogen uptake, agronomic N use efficiency (AE_N), N recovery efficiency (RE_N), N_2O-N emission and GWP unit yield of rice grown with different urea briquette

Treatments	Yield (t ha^{-1})	AE_N (kg kg^{-1})	N uptake (kg ha^{-1})	RE_N (%)	N_2O-N (kg ha^{-1})	GWP unit yield (kg CO_2 equivalent t^{-1})
Control	3.2 e		52.6 d		0.55 c	79.6 a
Urea granule	5.1 d	18.2 d	86.5 e	33.8 d	0.79 a	73.1 a
UPGB	5.9 b	26.2 ba	100.6ba	47.9ba	0.72 b	57.2bc
UFAB	6.2 a	29.5 a	106.3 a	53.6 a	0.72 b	54.0 c
USPB	5.4 c	21.6 c	93.2 c	40.6 dc	0.72 b	62.4 b
UNKB	5.5 c	22.1 c	94.8bc	42.1bc	0.71 b	60.9 b
URHB	5.4 c	21.9 c	92.9 c	40.3 dc	0.74 ba	63.5 b
UB	5.8 b	26.0 b	97.0 bc	44.3bc	0.72 b	57.3bc
L.S.D. ($P \leq 0.05$)	0.32	3.2	6.4	6.7	0.06	6.4

8. Development and evaluation of urea briquette applicator

Five hand-operated applicators for basal and top dressing of urea briquette were developed and evaluated for placement of circular shape urea briquettes in line transplanted rice. Out of these five applicators, three applicators were continuous type and two applicators were non-continuous type applicators. The details of these applicators are given below.

8.1 Manually pulled two row briquette applicator (UBA I)

Two row briquette applicator (UBA-I) consists of two hoppers, frame, two cup type metering rollers, one axle, one ground wheel and one handle fitted in the frame (plate 9). It was made by using material angle iron, GI sheet, etc. The applicator can be used for top dressing and for basal application. The removable furrow openers were fitted for both rows. The furrow opens by furrow openers closes immediately by float after placement of urea briquette. During application, the skids work in the middle of alternate plant rows, leaving the middle row without application for the operator to walk in that row. This process distributes briquettes evenly between plant rows and two rows share the banded fertilizer.

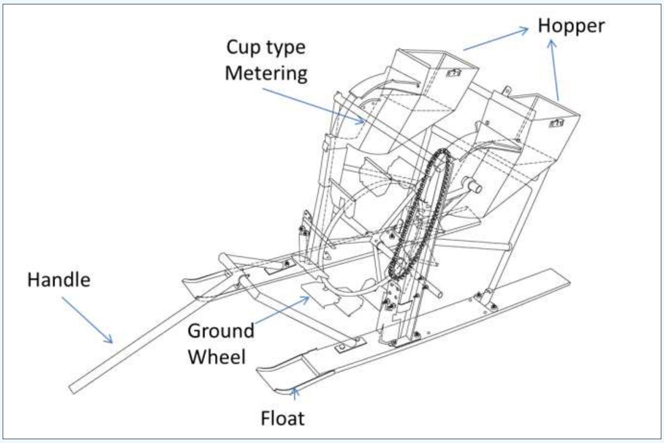


Plate 9. Manually pulled two row briquette applicator

8.2 Manually pulled three row urea briquette applicator (UBA II)

Manually pulled three row urea briquette applicator (UBA-II) consists of three hoppers, frame, three cup type metering roller, one axle, one ground wheel and one handle fitted in the frame (plate 10). It is made by using material angle iron, GI sheet, etc. The applicator can be used for basal application only. The removable furrow openers were fitted for all rows. Two ground wheel support applicator from both ends and four cup in metering unit gives the uniform placement of urea briquettes.

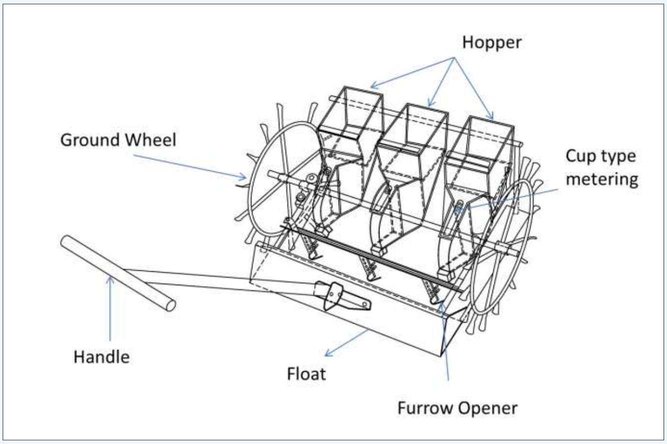
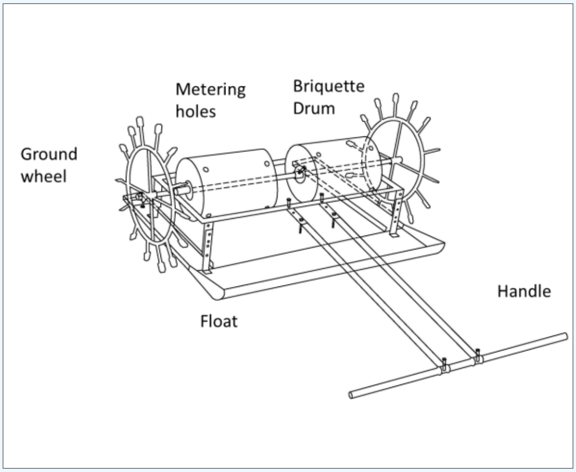


Plate 10. Manually pulled three row briquette applicator

8.3 Manually pulled four row drum type urea briquette applicator (UBA III)

Manually pulled four row drum type urea briquette applicator (UBA-III) consists of two drums, frame, one axle, two ground wheels and one handle fitted in the frame (plate 11). It is made of using material angle iron, GI sheet, MS flat etc. The applicator is useful for basal application. The working of applicator is similar to drum seeder. Operator has to pull the applicator so the urea briquettes filled in the drums dropped on field in a uniform manner. Two ground wheels support the applicator from both ends and float gives easy movement in puddled field condition.



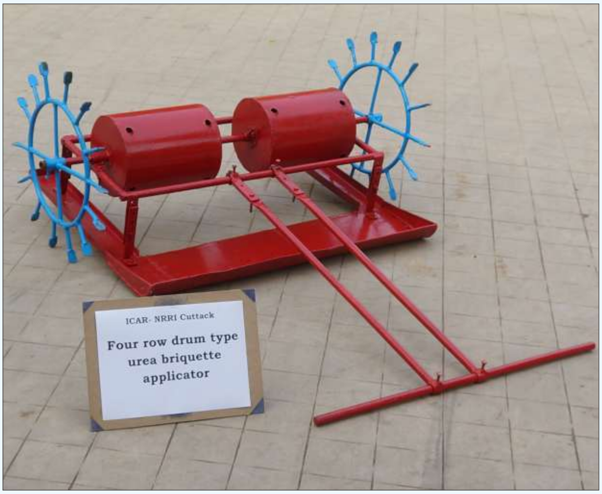


Plate 11. Manually pulled four row briquette applicator

8.4 Urea briquette applicator mounted on conoweeder for top dressing (UBAIV)

An attachment behind the cono weeder (UBA-IV) can apply urea briquettes simultaneously with weeding operation. It consists of two cones, one float, one briquette hopper, briquette delivery control system, and one handle fitted in the frame (plate 12). It is made of using material angle iron, GI sheet, MS flat etc. The machine is useful for weeding between rows of wet land paddy crop and urea briquette application. The working of applicator is similar to cono weeder, operator has to push the weeder and at same time at some interval push the clutch fitted on the handle to place one or two urea briquettes at a time. The efficiency of the urea briquette placement depends on the operator's ability to give forward and backward movement for weeding and at the same time push the clutch for dropping of urea briquettes.

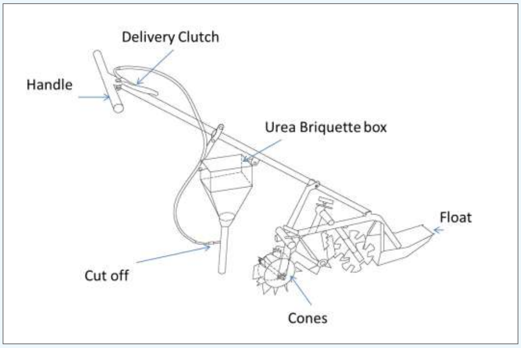


Plate 12. Urea briquette applicator mounted on conoweeder

8.5 Injector type briquette applicator for both basal and top dressing (UBAV)

It is a simple device carry in hands to place the urea briquette deep in the soil. Operator has to put urea briquette in the funnel and push the handle to place the briquette 5-6 cm deep in the soil. After every push, operator has to move forward. Handle, funnel, delivery tube and plunger assembly are made of using PVC pipes and depth control ring is made of MS flat (plate 13). It is light in weight and easy to carry. Specifications of these applicators are given in table 5.

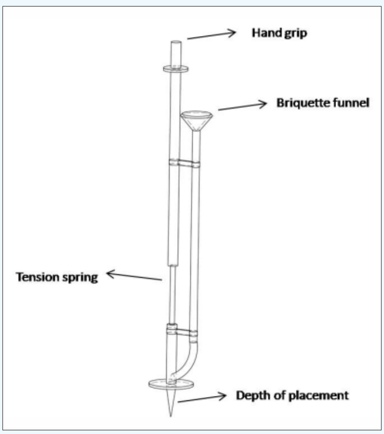


Plate 13. Injector type briquette applicator

Table 5 Brief specification of urea briquette applicators

S. No.	Particular	UBA I	UBA II	UBA III	UBA IV	UBA V
1	Overall dimensions, mm (L x W x H)	990 × 470 × 610	600 × 730 × 480	720 × 940 × 330	320×110×370	1200 ×150 × 1200
2	Ground wheel diameter, mm	300	480	500	--	--
3	Handle length, mm	900	870	870	1180	100
4	Float length, mm	1000	700	720	290	--
5	Weight without load, kg	14	20.5	14	9.3	1.66

8.6 Preparation of urea briquette suitable for mechanical applicators

Three continues type applicator (UBA I, II and III) were used and to control the application rate of urea briquette hopper can be adjusted for different briquette delivery rate. In UBA IV & V application rate of urea briquettes was depend on the operator's accuracy. Before field test these applicators were tested in laboratory for their application rate of urea briquette (average 1g) and delivery rate of urea was found 160 kg ha^{-1} for UBA I and V, 180 kg ha^{-1} for UBA II & IV and 192 kg ha^{-1} for UBA III. The application of N was found 94 kg ha^{-1}, 105 kg ha^{-1}, 113 kg ha^{-1}, 106 kg $ha^{-1}$and 94 kg ha^{-1} by UBA I, II, III, IV & V, respectively. To get the optimum application rate of N for basal application (40 kg ha^{-1}) and top dressing (20 kg ha^{-1}) there was need to reduce the application rate. If the size of briquettes were reduced than the performance of applicators was affected so filler materials were used to get optimum N application rate. The required proportion of filler material added with urea to get optimum N application by using applicators were given in table 6.

Table 6 Proportion of urea to filler material to get optimum N application rate

Code	UBA I	UBA II	UBA III	UBA IV	UBA V
UPGB	1:1.2	1.5:1	1:1.7	1:4.0	1:3.5
UFAB	1.4:1	1:1	1:1	1:2.9	1:2.4
USPB	1.2:1	1:1	1:1.1	1:3	1:2.6
UNKB	2.2:1	1.6:1	1.4:1	1: 2.2	1:1.9
URHB	2.1:1	1.5:1	1.3:1	1:2.3	1:1.9

Addition of filler material was done by the use of binder material to increase the strength of urea briquette so the breakage of urea was minimum during operation of applicators. Urea briquette size and weight was changed due to addition of the filler material and the average weight of one briquette was 1.41g, 1.08g, 1.20g, 0.96g, and 0.98g for UPGB, UFAB, USPB, UNKB, and URHB, respectively. Application rate was also changed after adding of filler material and binder. Actual delivery rate of briquettes made with filler material was calculated by calibrating the applicators in laboratory. Average of three replications was taken to finalize the application rate of these applicators (table 7).

Table 7 Rate of urea briquette application (kg ha^{-1}) using different applicator

Code	UBA I	UBA II	UBA III	UBA IV	UBA V
UB	160.0	180.0	192.0	180.0	160.0
UPGB	225.6	253.8	270.7	253.8	225.6
UFAB	172.8	194.4	207.4	194.4	172.8
USPB	192.0	216.0	230.4	216.0	192.0
UNKB	153.6	172.8	184.3	172.8	153.6
URHB	156.8	176.4	188.2	176.4	156.8

8.7 Comparative performance of applicators

The development process of these five applicators undergoes a phase in which these five applicators repeated evaluated and refined as per outcome of lab testing results. After satisfactory performance in lab testing, these applicators were evaluated in actual field conditions. All the urea briquette applicators were evaluated for their operating speed, field capacity, missing rate and multiple dropping rate using elliptical shaped shape urea briquettes having average weight of 1 g without any filler material (table 8). At average operating speed of 0.8, 0.92, 1.02, 1.4 and 0.78 km hr^{-1} the effective field capacity was found 0.070, 0.082, 0.06, 0.025 and 0.021 km hr^{-1} for UBA-I, II, II, IV and V respectively. Urea briquette applicator can save time up to 78.5 , 82.8 , 78.5 , 42.8 and 31.4 % over hand application by using UBA-I, II, II, IV and V, respectively. UBA-III cannot able to place the briquettes in depth and only gives uniform application above the soil surface. For basal application UBA-II performed better as comparison to UBA-I in terms of UB missing percentage. Among all the applicators the performance of UBA-V in terms of uniformity in depth and distance of placement was better, additionally missing rate of UB was nil for UBA-V, however labour requirement was high and it could be beneficial for small land holding farmers. Performance results of applicators are given in table 8. Deep placement of urea results in reduced rate of urea application with saving in cost of application over hand placement which provides economic benefits to the farmers with minimal losses.

Table 8 Performance and features of urea briquette applicators

S. No.	Particular	UBA I	UBA II	UBA III	UBA IV	UBA V
1	Row to row spacing, mm	350-400 (Adjustable)	200	220	--	--
2	Depth of operation, mm	50-80 (Adjustable)	40-100 (Adjustable)	--	--	60
3	Placement distance, mm	100	100	80-120	Manual adjustment	Manual adjustment
4	Speed of operation, km h^{-1}	0.8	0.92	1.02	1.4	0.78
5	Effective field capacity, ha h^{-1}	0.070	0.082	0.06	0.025	0.021
6	Missing rate, %	13-15	6-8	1-3	4-6	Nil
7	Multiple dropping rate, %	6-7	11-13	22-25	15-18	Nil
8	UB application rate, Kg ha^{-1}	160	180	192	180	160
9	Labour Requirement man-h ha^{-1}	15	12	15	40	48

9 Enhancing nitrogen use efficiency by deep placement of urea through three row briquette applicator

Field trials were conducted during dry and wet seasons of year 2014 with variety Naveen and Gayatri, respectively to evaluate the performance of urea briquette applicator on yield and NUE of transplanted rice (plate 14). Seven treatments including T1: No N; T2: N as urea granule broadcasted in conventional 3 splits i.e. 50% basal, 25% at maximum tillering and 25% at panicle initiation; T3: N as urea granule broadcasted in three splits as per CLCC reading; T4: : N as urea granule applied in three splits, first split (30%) was applied using fertilizer applicator, rest two splits were broadcasted as per CLCC reading; T5: N as urea briquette manually deep placed in conventional 3 splits i.e. 50% basal, 25% at maximum tillering and 25% at panicle initiation; T6: N as urea briquette manually deep placed in three splits as per CLCC reading; and T7: N as urea briquette applied in three splits 1st split (30%) was applied using briquette applicator and rest two splits were manually deep placed as per CLCC reading; Varieties were Naveen and Gayatri in dry and wet seasons respectively (table 9). All the treatments were replicated three times in a randomized block design. The dose of N was 100 kg ha^{-1} in and 80 kg ha^{-1} for dry and wet season, respectively. Phosphorous and potassium were applied to all treatment as per recommendation at the time of transplanting. Crop was harvested at maturity, observations on grain and straw yield were recorded, grain and straw samples were analyses for N content to estimate N uptake and N use efficiencies.

Plate 14. Three row urea briquette applicator in operation

Table 9 Yield, nitrogen uptake, agronomic N use efficiency (AE_N), N recovery efficiency (RE_N) of transplanted rice under different N management practices.

Treatments	Yield ($t\ ha^{-1}$)		AE_N ($kg\ kg^{-1}$)		N uptake ($kg\ ha^{-1}$)		RE_N (%)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
T1	2.9 d	2.8 d	-	-	50.8 d	45.8 d	-	-
T2	4.9 c	4.2 c	19.7 c	17.3 c	89.1 c	71.6 c	38.3 c	32.3 c
T3	5.4 b	4.7 b	24.9 b	23.4 b	97.3 b	80.6 b	46.5 b	43.6 b
T4	5.4 b	4.7 b	24.7 b	23.5 b	93.6bc	80.5 b	42.8bc	43.4 b
T5	5.4 b	4.8 b	25.1 b	24.4 b	94.9bc	82.3ab	44.1bc	45.7ba
T6	5.9 a	5.2 a	30.2 a	29.9 a	105.5 a	89.8 a	54.7 a	55.1 a
T7	5.4b	4.8b	25.0b	30.1 a	101.6ab	85.6ab	50.8ab	49.7ab
L.S.D. ($P \leqslant 0.05$)	0.43	0.34	4.2	4.2	6.9	6.9	7.4	10.0

Deep placement of urea briquettes manually or mechanical applicator resulted in the higher yield, N uptake and N use efficiency than broadcasting of urea granules. The highest yield was recorded when urea briquettes are deep placed manually following CLCC reading. Application of urea briquette using briquette applicator produced higher yield than broadcasting of urea granule but less yields than manual deep placement.

10. Nitrous oxide emission after deep placement of urea using two row & three row urea briquette applicator

In a field experiment during dry season, 2016 altogether six treatments, *viz.* control/no nitrogen (T1), pilled urea broadcasting (T2), prilled urea manual placement (T3), urea briquette manual placement (T4), three row briquette applicator (basal) + urea briquette manual placement (T5), and two row briquette applicator (basal) + urea briquette manual placement (T6) were tested in randomized block design (RBD). A uniform dose of fertilizer nitrogen @ 80 kg N ha^{-1} was applied in three splits (40-20-20 kg ha^{-1}) in the form of urea. Half of the dose applied as basal during land preparation and the rest were divided in maximum tillering and panicle initiation stage. The nitrous oxide emission was measured using a manual chamber method followed by its determination in a gas chromatograph. The lowest emission was recorded in T6 treatment which was 38.48 μg m^{-2} hr^{-1} (except control) over all the stages of growth of the rice crop (cv. Naveen). Stage wise observation clearly showed (Figure 3) the average emission was the highest at PI stage (46.19 μg m^{-2} hr^{-1}) followed by AT stage (41.62 μg m^{-2} hr^{-1}). Such results can be explained by the application of nitrogenous fertilizers at those stages. The average emission of nitrous oxide for other stages can be arranged in the order of decreasing as MT (41.48 μg m^{-2} hr^{-1}) >FL (32.95 μg m^{-2} hr^{-1}) >GF (26.97 μg m^{-2} hr^{-1}).In our study, the treatments comprised of prilled urea (T2 and T3) observed more loss of nitrous oxide than the treatments comprised of urea briquette. We also observed that machine placements of urea briquette (T5 and T6) gave better results (less emission of nitrous oxide) than the manual placement (T4), which may be due to a more precise depth of application. Also, we found more nitrous oxide emission in broadcasting (T2) than the placement (T3).

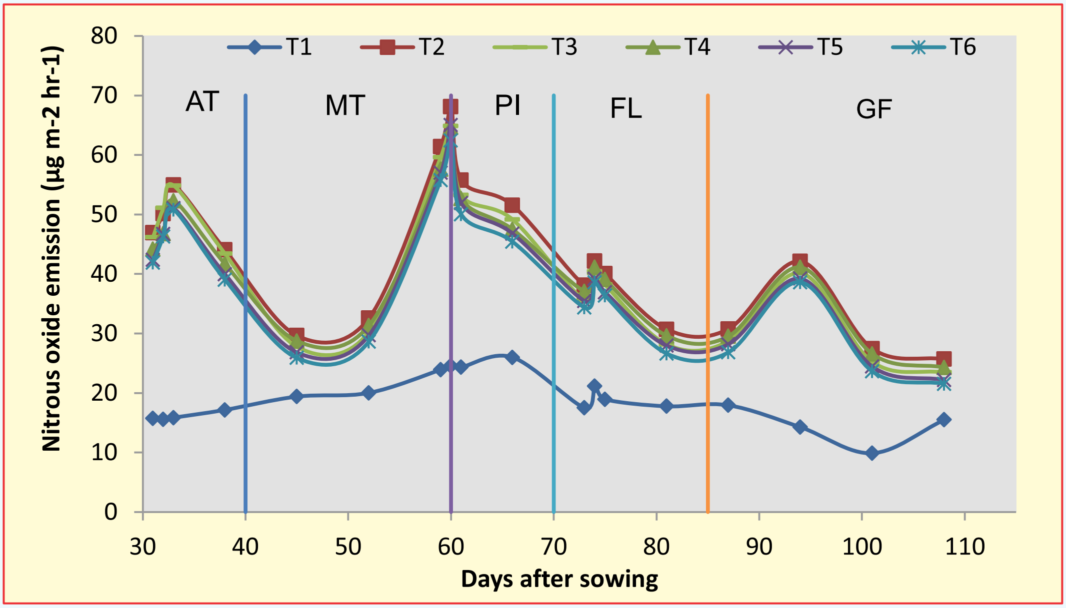


Figure 3. Nitrous oxide emission (μg m^{-2} hr^{-1}) at different stages of rice growth(AT: active tillering, MT: maximum tillering, PI: panicle initiation, FL: flowering, and GF: grain filling to maturity stage)

Among the different treatments the highest increase (%) in nitrous oxide emission over control (table 10) was recorded in prilled urea broadcasting (T2, 131.9%) followed by prilled urea manual placement (T3, 122.3%), urea briquette manual placement (T4, 120.9%), three row briquette applicator (basal) + urea briquette manual placement (T5, 113.1%), and two row briquette (basal) + urea briquette manual placement (T6, 107.7%). The increase in emission (%) over control was much more in active tillering followed by panicle initiation.

Table 10 Increase (%) in nitrous oxide emission over control at different stages of rice growth

Stages of rice growth	% increase in emission over control				
	T2	T3	T4	T5	T6
Active Tillering (AT, n=4)	205.9	205.2	188.5	181.1	178.0
Maximum Tillering (MT, n=3)	112.4	101.9	102.1	97.3	90.9
Panicle Initiation (PI, n=3)	113.6	103.8	99.4	96.6	90.0
Flowering (FL, n=4)	100.3	88.5	94.8	85.0	80.1
Grain Filling (GF, n=4)	127.5	112.0	119.6	105.7	99.6
Overall (n= 18)	131.9	122.3	120.9	113.1	107.7

11. Ammonia volatilization

In the same experiment mentioned in section 10, ammonia volatilization was also measured (figure 4). Application urea influences NH_3 volatilization by shifting the ionic balance from NH_4 to NH_3 as soil pH increases in response to a higher demand for protons during the hydrolysis process (Rochette et al., 2009).

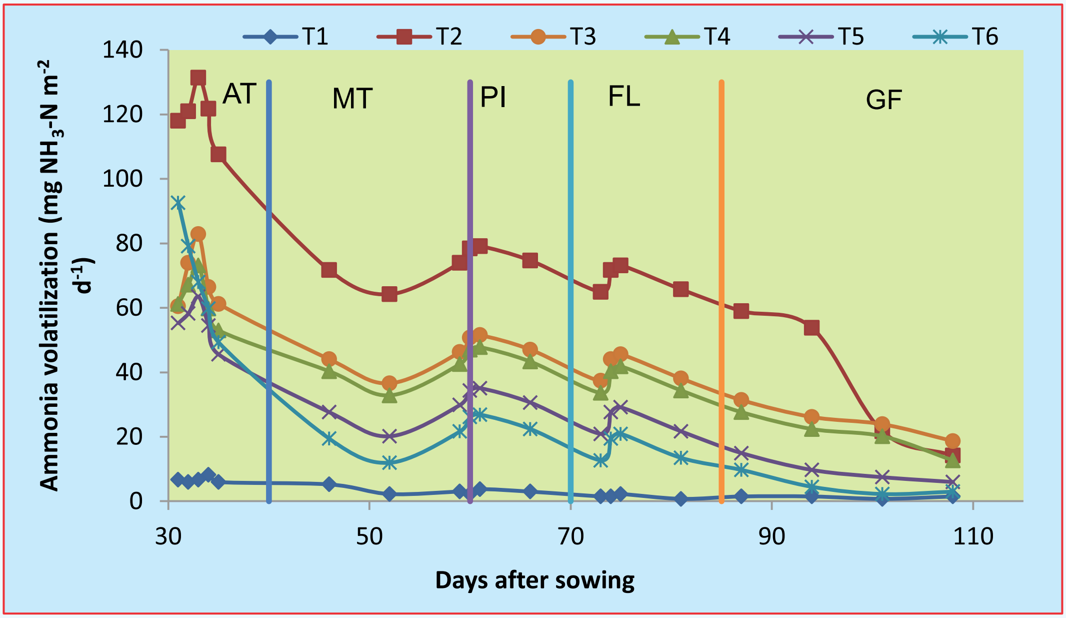


Figure 4. Ammonia volatilization (mg NH_3-N$m^{-2}d^{-1}$) at different stages of rice growth (AT: active tillering, MT: maximum tillering, PI: panicle initiation, FL: flowering, and GF: grain filling to maturity stage)

The highest ammonia volatilization was recorded in T_2 over all other treatments. The lowest value was recorded in control throughout the period of observation. The average ammonia volatilization of all observations can be arranged in the order of decreasing as T_2 (77.15 mg NH_3-$Nm^{-2}d^{-1}$) > T_3 (46.65 mg NH_3-$Nm^{-2}d^{-1}$) > T_4 (42.17 mg NH_3-$Nm^{-2}d^{-1}$) > T_5 (31.17 mg NH_3-$Nm^{-2}d^{-1}$) > T_6 (29.63 mg NH_3-$Nm^{-2}d^{-1}$)> T_1 (3.38 mg NH_3-$Nm^{-2}d^{-1}$). The average stage wise emission was the highest at AT stage (63.94 mg NH_3-$Nm^{-2}d^{-1}$) followed by PI stage (35.34 mg NH_3-$Nm^{-2}d^{-1}$), MT (34.69mg NH_3-$Nm^{-2}d^{-1}$) FL (26.34 mg NH_3-$Nm^{-2}d^{-1}$), and GF (16.43 mg NH_3-$Nm^{-2}d^{-1}$). The yield ranged 3.07 -5.49 t ha^{-1} (figure 5). The yield was highest in T_6 (5.49 t ha^{-1}) followed by T_5 (5.44 t ha^{-1}), T4 (5.16 t ha^{-1}), T_3 (5.06 t ha^{-1}), T_2 (5.04 t ha^{-1}) and T_1 (3.07 t ha^{-1}).

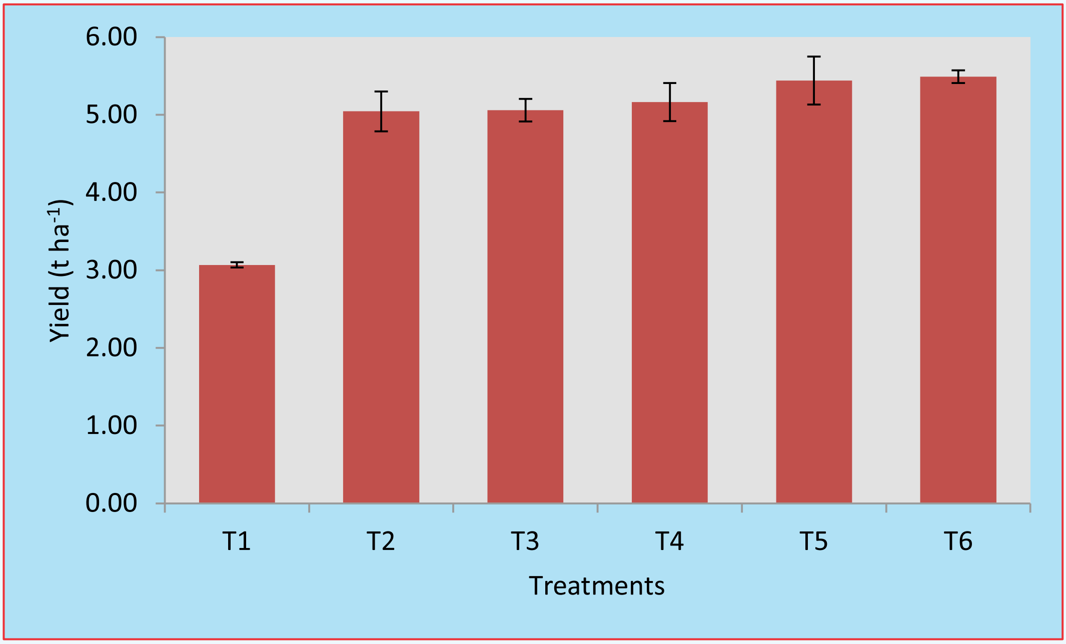


Figure 5. Grain yield of rice after deep placement of urea using urea briquette applicator

12. Technology up-scaling (Demonstration at farmer's field)

Farmer's field demonstration of developed technology was conducted at farmer's field during *dry* season 2016. Demonstration of UBA-I & II was conducted on date 25 February 2016 and UBA-V on 22 March 2016 at village Singiri PO Chasapa Block Balikunda District Jagatsinghpur, Odisha in four plots having area of 450 m^2 (plate 15). Rice variety Naveen was selected for demonstration. Rice husk was used as filler material in order to get optimum N application rate. Four treatments, *viz*. T1 [UBA-I (basal) + UBA V (top dressing)], T2 [UBA II (Basal) + UBA V (Top dressing)], T3 [Manual placement of urea briquettes (basal+ top dressing)] and T4 [farmers practice (Manual broadcasting of prilled urea)] were selected.

Two row urea briqquette applicator (basal application)

Three row urea briquette applicator (basal application)

Injector type urea briquette applicator (top dressing)

Plate 15. Urea briquette applicators in operation at farmers field

Fertilizer nitrogen was applied @ 80 kg N ha^{-1} in three splits (50%-25%-25%): as 50% basal, 25% at maximum tillering and 25% at panicle initiation. During operation, the field capacity of UBA-I, UBA-II & UBA-V was found 0.068 ha h^{-1}, 0.082 ha h^{-1} and 0.023 ha h^{-1}. Increase in grain yield of 19.6 % was observed with T1 over T4 (figure 6). Based on demonstration results three row urea briquette applicator for basal application and Injector type applicator for top dressing were recommended for deep placement of urea briquettes.

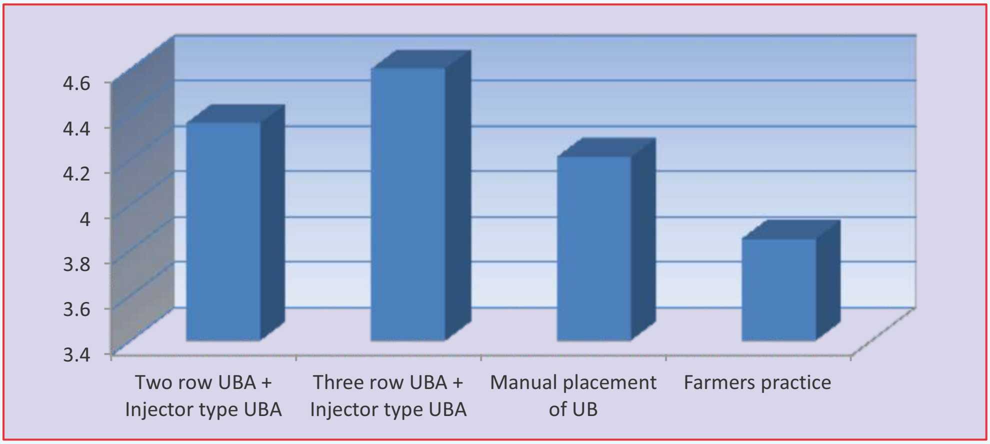


Figure 6. Grain yield (t ha^{-1}) influenced by placement of urea

13. Conclusion

Placement of urea briquettes at a depth of 5-7 cm enhanced yield and N use efficiency and significantly reduced N loss and in the form of N_2O emission. Thus, this technology can be recommended as environmentally safe and agronomically efficient technology for low land rice of Eastern India where soils are mostly heavy textured with characteristic low percolation rate. Urea briquettes can be produced in small-scale at village level, using briquetting machines through various Government schemes and supplied to farmers. However, care should be taken use appropriate binders while preparing the briquettes in order to reduce loss of urea due to breakage. Locally available environmentally safe industrial/biological wastes such as fly ash, phospho-gypsum etc. can be used as filler material along with suitable binder to reduce urea concentration in briquette and enhance the strength of briquette without affecting its efficiency. Breakability of urea briquette often interferes with the operation of applicator and prevents uniform dropping of briquettes. High labour cost of manual deep placement method and non-availability of easy to use, appropriate urea briquette applicator are major impediments in the adoption of this practice by the framers. Research is needed to further fine tune and develop power operated urea briquette applicators for both basal application and top dressing to reduce the drudgery involved in this operation.

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ICAR - National Rice Research Institute
Cuttack-753 006, Odisha, India
Phone: 0671-2367757, Fax: 91-671-2367663
Email: director.nrri@icar.gov.in, crrictc@nic.in
Website: http://www.crri.nic.in