QUANTIFYING THE PERFORMANCE OF UREA DEEP PLACEMENT APPLICATORS IN BORO RICE CULTIVATION

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CERTIFICATE

*This is to certify that the thesis entitled " **Quantifying the performance of urea deep placement applicators in boro rice cultivation"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **SOIL SCIENCE,** embodies the results of a piece of bona fide research work carried out by **MD.ARIFUR RAHMAN,** Registration. No.* **11-04586** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

____

Dated:

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DEDICATED TO

MY

BELOVED PARENTS

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The Author

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ABSTRACT

A research work was carried out at the Research Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2015 to April 2016 in order to determine the suitable urea deep placement applicator and observing the growth performance with a view to increase the grain yield of boro rice. The experiment consisted of one factors. Factor: T_0 = Control plot, T_1 = Application of urea briquette by hand placement, T_2 = Application of urea briquette by battery- powered applicator, T_3 = Application of urea briquette by BRRI applicator, T_4 = Application of urea briquette by injector applicator, T_5 = Application of urea briquette by push- type applicator, T_6 = Application of prilled urea by broadcast method. The experiment was set up following randomized complete block design with three replications. Experimental results showed that nitrogen sources and application methods had significant effect on plant height, effective tiller no/ hill, grain yield, straw yield, biological yield and harvest index. The application of T_3 treatment showed the highest grain yield (5.82 t /ha) and straw yield (7.28 t/ha) than any other sources of nitrogen and methods of application. Experimental results showed that nitrogen sources and application methods had significant effect on NH_4^+ concentration in standing water of experimental paddy soil. The higher ammonium concentrations (9.17 ppm) were found in the water of T_6 (Application of prilled urea by broadcast method) treatment during 1-7 days of water samples. The soil ammonium concentrations were significantly affected by nitrogen sources and application methods. The higher soil ammonium concentrations (120.3 mg/kg dry soil) were observed in the treatment of T_3 (Application of urea briquette by BRRI applicator) during 1-7 days of collected soil samples.

Findings revealed that when urea briquette was placed with BRRI applicator showed the superiority over other sources of nitrogen and application methods to produce higher grain yield of boro rice.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BRRI	=	Bangladesh Rice Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance
USG	=	Urea Super Granule

CHAPTER I

INTRODUCTION

Urea is widely used nitrogen fertilizer for rice cultivation. Statistics indicates that about 80% of urea is used for rice production. But only 15 to 35% of the total applied nitrogen is used by the rice plant (Prasad and Datta, 1979). The low level of nitrogen recovery by rice plant is generally caused by huge losses of nitrogen from soil water- plant complex. Nitrogen loss processes are due to ammonia volatilization, de-nitrification, runoff, seepage, and leaching. Thus there is a great need to improve nitrogen use efficiency for rice production. Due to excessive loss of nitrogen, farmers in Bangladesh have not been able to make more effective use of fertilizer to boost their rice yields. In the present (granular/prilled urea) method of application, only 40% of the applied urea is used by the plant and the remaining 60% is lost by air, water or leaching under the ground (Iqbal, 2009). Another statistics showed that two out of three bags of urea go un-used in wet land rice production (Amit, 2011).With deep placement methods, fertilizers are placed in the soil irrespective of the position of seed, seedling or growing plants before sowing or after sowing the crops .Deep placement of nitrogenous fertilizer (N) is an alternative for increasing the N use efficiency of wetland rice besides minimizing the adverse effects of fertilizers on the environment (Bautista et al. 2001). On the contrary, deep placement of urea is environment friendly having minimal loss (Ahamed, 2012). Bangladesh has substantially increased its rice production through increased use of inorganic fertilizer. The nature and degree of loss depends upon soil, climatic conditions, nitrogen fertilizer and water management practices. Much effort has been made to improve fertilizer use efficiencies in lowland rice production. Deep placement of nitrogen fertilizer into the anaerobic soil zone is an effective method to reduce volatilization loss. At present, Urea Super Granule (USG) has been started to be used in puddled rice field and found to be economic and effective method of urea fertilizer application in rice field. Hand placement of USG of 1.8-2.7 g sizes into soil of flood water has been resulted less loss of nitrogen, greater nitrogen recovery and higher yield than conventional nitrogen application method (Diamond, 1985). Instead of normal dose of 247 kg of granular urea, only 165 kg/ha of USG is required (35% less) and it increases rice yield up to 20% (Hoque,2008).

Depending on agroclimate and nitrogen use, deep-placed USG can save urea fertilizer up to 65% with an average of 33% and increase grain yields up to 50% with an average of 15% to 20% over the same amount of split-applied nitrogen as prilled urea, especially in the lower range of nitrogen rates (Savant and Stangel, 1990). But, deep placement of USG by hand requires more labour and cost. Labor shortage in rice production is one of the major constraints which cause due to migration of people to town and need mechanization for rice production (Mohammada et al., 2011).The hand placement of USG is labor intensive and very slow i.e. 0.07 to 0.12 ha/workday (Savant et al., 1992). Also hand placement of USG is tedious work and caused back pain. Unfortunately, farmers have not been able to be benefited from these findings, primarily because they have no suitable fertilizer placement equipment. Cost of fertilizer is increasing day by day. Efforts should be made to develop a low cost, efficient fertilizer application machine for placing the fertilizer at required depths for different crops. Thus fertilizer use efficiency will be high, resulting in higher yield and lower production cost. To minimize nitrogen loss, USG application may be a good technology to increase rice yield as well as the reduction of production cost. Minimum effort has been made in the county to develop different fertilizer applicators for improving fertilizer use efficiency.

To solve the problem of USG placement by hand, Push type applicator, BRRI Prill urea applicator, Injector applicator, Push type battery power applicator, applicator for puddled rice field has been developed in Farm Machinery and Postharvest Process (FMP) Engineering Division of Bangladesh Agricultural Research Institute (BARI) (Wohab et al., 2009). DAE and IFDC in collaboration. BARI have been demonstrating this technology (BARI USG the applicator) in 68 Upazilas (The daily Star, 27 June, 2011). Nowadays USG application in paddy field is an innovative technology to reduce the nitrogen fertilizer losses in the field. Manual application of USG in the field by hand between four seedlings is very much time consuming, costly and back breaking task. As a result different models of USG applicator were developed in home and abroad. Most of the applicators are manually pushed or pull type. An applicator was designed and developed to operate by a DC electric motor. In this machine 12 Volt 9 AH rechargeable battery was used. Power was transmitted by pulley and v-belt from the motor to the driven wheel. The average missing rate was found 4.84% and the average applicator capacity was found 19.37 kg/hr and the average field capacity was found 0.0924 ha/hr. When the machine operated in the unpuddled land, distance between two dropped guti was found averagely 38.76 cm. By selecting more powerful motor, the machine performance can be improved. Push type applicator were designed during 2011–2015 to deep-place fertilizer briquettes in puddled rice fields. Push type design developed earlier by the Bangladesh Agriculture Research Institute. In particular, the width of the furrow opener and skid was modified to ensure the precision placement of urea briquettes (UB) to 5–7-cm soil depth and coverage of the briquettes with soil. The injector-type applicator, which has four mechanisms—feeding, metering, delivery, and placement—weighs 1.5 kg. Field testing across different sites and seasons showed that the push-type applicator significantly reduced the labor requirement to 15–20 h/ha compared to the hand placement (28–50 h/ha). The applicator consistently placed UB at proper depth (7 to 8 cm), which resulted in low concentrations of urea N (<7 ppm) in about 4 cm of floodwater 1 day after placement. Bangladesh Rice Research Institute (BRRI) had designed and developed a push type USG applicator during 2008 (Hossen *et al.,* 2013). This applicator applies USG at 6 to 7cm depth below the soil surface in the middle of four bunches of rice seedlings. When USG is applied by hand, 28 hours are required per hectare, whereas only 10 hours are required by the applicator. The USG applicator reduced the human drudgery. International Fertilizer Development Corporation (IFDC) has been trying to popularize the USG technology in different countries since long time. During operation of the USG applicator, there is a possibility to make bridge while rotating metering device due to oval shape of USG. Two USGs may drop at a time due to under size of the briquette. Besides, the USG machine would not perform satisfactory when the hopper is fully loaded. Moreover, proper size of USG was not available in the market and some percentage of urea is lost during the formation of USG. Cost of installing the USG briquetting machine was also high. To overcome these problems, in 2013, the scientists of Farm Machinery and Postharvest Technology Division of BRRI had developed the applicator to deep place prilled urea in between two rows plant in one time (Rahman *et al.,* 2014).

There are many applicators in Bangladesh which are very effective for deep placement of prilled urea in soil. Every applicator is effective but they are comparable for mechanical problem, technical knowledge of labour and working performance of the applicators. Missing of USG in any place that would affect crop production. Perfect placement of urea super granule depends on perfect applicator. So quantifying the performance of urea deep placement applicators are very important for effective placement of USG. This study was therefore, undertaken to quantifying the field performance of urea deep placement applicator.

OBJECTIVES

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken with the following objective :

1. To find out appropriate applicator for placing USG in appropriate depth of paddy field.

2. To observe the efficiency of USG rate by certain applicator.

3. To observe the effect of urea super granule and prilled urea on the availability of ammonium concentration in paddy soil and standing water in paddy field.

4. To find out the correlation between soil ammonium and yield of boro rice

CHAPTER II

REVIEW OF LITERATURE

High production of any crops depends on manipulation of basic ingredients of agriculture. Growth and yield of rice is greatly influenced by environmental factors like day length or photoperiod, temperature, humidity, variety and agronomic practices such as transplanting time, spacing and number of seedlings/hill.Nitrogen is one of the macro-nutrients used in Bangladesh in the form of urea. There are different forms of urea. USG is one of them which greatly influences crop yield. Prilled urea is another form of urea. Many experiments were conducted by national and international institutions. A number of studies were conducted in Bangladesh on different forms of urea as the source of nitrogen especially prilled urea dose and dose of USG also an important factor in research farms and farmers filed under different agro-ecological conditions. An attempt has been made in this chapter to review the literatures and research finding on the level of prilled urea and USG application as the source of nitrogen for boro rice production.

2. Effect of N-fertilizer

2.1 Number of effective tillers /hill

Ahsan (1996) stated that tillering is strongly correlated with nitrogen content of the plant. The incremental level of nitrogen increase the number of tiller hill^{-1}. Results showed that the highest number of tiller/ hill (31) was obtained at 150 kg N ha^{-1} and declined with the lower level of nitrogen.

Alam (2002) observed that total tillers hill^{-1} and effective tillers hill^{-1}increased significantly with the increase of level of USG, when USG was applied as one, two, three and four granules/4 hills during the boro season.

Hasan (2007) conducted an experiment during the *aman* season of 2006 and recorded the increased number of tillers hill $^{-1}$with increased nitrogen level as USG.

Idris and Matin (1990) noticed that the maximum number of tillers hill $^{-1}$ was produced with 140 kg N ha^{-1} which was statistically similar to 60, 80, 100 and 120 kg N ha^{-1}. The minimum number of tillers hill^{-1} was obtained from the control treatment (0 kg N ha^{-1}).

Singh and Shivay (2003) evaluated that the effective tillers hill $^{-1}$ was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tillers hill^{-1}.

Kumar *et al* (1995) stated that an increase in N level from 80 to 120 kg N ha^{-1} significantly increased total tillers hill^{-1}.

2.2 Plant height

Razib (2010) observed the highest plant height (100.2 cm) of rice when 120 kg N ha^{-1}was applied.

Mizan (2010) reported that the highest plant height (98.32 cm) was obtained from 160 kg N ha $^{-1}$ followed by 120 kg N ha^{-1}.

Ahammed (2008) observed that leaf area increased with increasing level of nitrogen application from 40 kg N ha^{-1} up to 120 kg N ha^{-1}.

Rahman (2007) found that effect of depth of placement of USG significantly influenced all growth characters and the yield attributes except plant height.

Mishra *et al*. (2000) reported that the application of 76 kg N ha^{-1} USG at 14 DAT increased plant height, panicle length, N uptake and consequently the grain and straw yields of lowland rice.

Ahmed *et al.* (2002) observed that among 5 levels, 80 kg N ha $^{-1}$gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application. Plants receiving no nitrogenous fertilizers were significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Meena *et al.* (2003) reported that between two levels of N 100 and 200 kg ha^{-1}, application of 200 kg ha^{-1} significantly increased the plant height (127.9 cm) of rice and total number of tillers $hill^{-1}$ (16.3).

Zohra (2012) conducted an experiment with 3 different T. *aman* varieties and highest plant height was recorded when 3 pellets of USG/4 adjacent hills were applied.

Alam (2002) found that plant height increased significantly with the increase of level of USG/4 hills. Rahman (2003) also observed that different level of USG did not affect the plant height.

Chowdhury *et al.* (1998) noted that the longest plant height of 112.1 cm was produced by nitrogen application at 100 kg ha^{-1} and was followed by 75 kg ha^{-1} due to the excellent vegetative growth of rice.

Sahrawat *et al.* (1999) found that nitrogen level significantly influenced plant height of rice. Increasing levels of nitrogen increased the plant height significantly up to 120 kg N ha^{-1}.

Salem (2006) reported that the nitrogen levels had a positive and significant effect on growth parameters of rice plants in boro season. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased leaf area index and plant height. The highest plant height at harvest was recorded about 92.81 cm when rice plants were fertilized with the highest nitrogen level of 70 kg ha^{-1}. On the contrary, the lowest value of the height was recorded about 80.21 cm when rice plants received no nitrogen fertilizer.

Thakur (1993) observed that the highest plant height of rice was obtained from 120 kg N ha^{-1} and the lowest one from the control.

2.3 Weight of 1000- grain (g)

Garcia and Azevedo (2000) conducted an experiment with 5 doses of nitrogen fertilizer (0, 50, 100, 150 and 200 kg N ha^{-1}) and concluded that weight of 1000-grains increased with increase in nitrogen fertilizer up to 150 kg N ha^{-1}.

Chopra and Sinha (2003) conducted an experiment with the treatments comprised of 4 N levels (0, 60, 120 and 180 kg N ha^{-1}) and results showed that N had significant effects on yield attributes such as plant height, panicles plant^{-1} and 1000-seed weight. Cumulative effects of yield attributing characters resulted in significant increase and seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1}.

Azam *et al.* (2009) conducted an experiment during the *aman* season with 3 different T. *aman* varieties by using both USG and prilled urea as a source of N. He observed that source and dose of nitrogen did not show significant effect on 1000-grain weight. The highest 1000-grain weight (24.70 g) was obtained with USG applied at 55 kg N ha^{-1} and lowest (24.09 g) 1000-grain weight was observed at 110 kg N ha^{-1} as PU.

Chopra and Chopra (2004) showed that N had significant effects on yield attributes such as plant height, panicle plant $^{-1}$ and 1000-grain weight. Cumulative effect of yield attributing and nutrient characters resulted in significant increase in seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1} and the control.

A field experiment was conducted by Maiti *et al.* (2003) during the boro season with the nitrogen fertilizer applied during transplanting, at the tillering and panicle initiation stages. They found increased number of higher number of panicles, number of filled grains panicle $^{-1}$, 1000-grain weight and grain yield.

Naseem *et al.* (1995) recorded lower 1000-grain weight in the control treatment than in the plots received fertilizer nitrogen.

2.4. Grain and straw yield

Ahmed *et al.* (2002) revealed that USG was more efficient than PU at all levels of nitrogen in producing all yield components and in turn, grain and straw yields. Placement of 160 kg N ha^{-1} as USG produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1}as USG and significantly superior to that obtained from any other level and source of nitrogen.

Rahman (2003) found that two USG per 4 hills produced the higher grain and straw yields (5.22 and 6.09 t ha^{-1}, respectively).

Miah *et al.* (2004) carried out an experiment with transplanted rice cv. BINA dhan 4. They found that the values of the parameters measured were higher with application of USG compared to application of urea.

Nayak and Panda (2002) carried out a field experiment on transformation of applied urea and its efficient utilization in rainfed lowland rice (*Oryza sativa* L.) and observed that management practices on grain and straw yields was good.

Surendra *et al*. (1995) applied N @ 0, 40, 80, 120 kg ha^{-1} from USG and urea dicyandiamide @ 80 kg N ha^{-1}. They observed that USG and urea dicyandiamide produced significantly more panicle $hill^{-1}$, grains $panicle^{-1}$, panicle weight and grain yield than PU @ 80 kg N ha^{-1} .

Sarkar *et al.* (2001) reported that application of nitrogen increased straw yield significantly up to 120 kg N ha^{-1}.

Pandey and Tiwari (1996) evaluated the rate of 87 kg N ha^{-1} as a basal application of USG and to dressing as PU and observed that grain yield and N use efficiency were the highest with N applied as a basal application of USG.

Dongarwar *et al.* (2003) conducted a field experiment in Shandara, Maharashtra, India to investigate the response of the rice (KJTRH-1), Jaya and Sawarna to 4 fertilizer rates i.e.75, 100, 125 and 150 kg N ha^{-1}. There was a significant increase in grain yield with successive increase in fertilizer rate. The highest grain yield (53.05 q ha^{-1}) was obtained with 150 kg N ha^{-1} and KJSTRH-1 produced a significant higher yield than Jaya (39.64 q ha^{-1}) and Sawarna (46.06 q ha^{-1}).

Rahman (2005) determined the nitrogen level and found that the grain yield of rice was increased with increasing nitrogen levels and the highest yield (4.19 t ha^{-1}) was attained with 150 kg N ha^{-1} while further increase in nitrogen level decreased the grain yield. It was estimated that the grain yield with 150 kg N ha^{-1} was 35.8, 18.9, 5.0 and 6.0% higher than those obtained with 0, 50, 100 and 200 kg N ha^{-1}, respectively.

Hasan (2007) found the effect of level of USG significantly influences all the yield attributes except 1000 grain weight. In his experiment, the highest grain and straw yields were found (5.20 and 7.45 t ha^{-1}, respectively) from the level of USG @ 3 pellets/4 hill or 90 kg N ha^{-1}as USG.

Singh and Gangwer (2009) claimed each incremental dose of nitrogen gave significantly higher straw yield.

Dwivedi *et al.* (2006) conducted a field experiments to evaluate the effects of nitrogen levels on growth and yield of hybrid rice. They found 184.07 kg N $ha^{-1}$was the optimum rate for highest yield.

Islam *et al.* (2011) carried out an experiment on the effectiveness of NPK briquette on rice in tidal flooded soil condition. They found that NPK briquettes, USG and prilled urea (PU) produced statistically similar grain yield but gave significantly higher grain yield than N control.

Elbadry *et al.* (2004) in pot and lysimeter experiment showed that the increasing level of N had statistically significant difference on growth parameters and yield attributes like dry weight, number of productive tillers, grain and straw yields of rice.

Azam (2009) conducted a field experiment during *aman* season involving 5 rates of N (0, two as prilled urea and two as USG) found that, highest straw yield (6.11 t ha^{-1}) was produced by 110 kg N ha^{-1} as USG.

Das (2011) found the highest grain yield (4.28 t ha^{-1}) of rice using the 240 kg prilled urea ha^{-1} and the lowest grain yield (3.06 t ha^{-1}) using the no nitrogen application in a field trial with prilled urea.

Nitrogen fertilizer was applied to the rice crop at the of 0, 96 and 144 kg N ha^{-1} in urea form and the main results indicated that increasing nitrogen levels up to 144 kg ha-1 significantly increased straw yield (Ebaid and Ghanem, 2000) and the highest when 87 kg N ha^{-1} was applied. Productive tillers also followed a similar trend.

Wopereis *et al.* (2002) stated that rice yields increased significantly as a result of N application on two N dressing (applied at the onset of tillering and at panicle initiation) with a total of approximately 120 kg N ha^{-1} in farmer's fields.

Singh and Gangwer (2009) claimed each incremental dose of nitrogen gave significantly higher straw yield. In a field experiment on agronomy field laboratory, BAU, Hussain (2008), evaluated that maximum utilization of N was possible due to proper application of N as USG placement or crop N demand. If the doses of N are higher or lower than demand, it will be overdose or deficiency of N and then yield will be reduced.

Mashkar and Thorat (2005) conducted a field experiment during the 1994 kharif season in Konkan, Maharashtra, India, to study the effects of different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}) on the N, P and K uptake and grain yield of scented rice cultivars (Pula Basmati 1, Kasturi, Indrayani and Sugandha). The different levels of N had significant effect in augmenting the uptake of N, P and K nutrients and grains as well as straw yield of rice. Application of 120 kg N ha^{-1} recorded significantly higher N, P and K uptake in rice compared to the rest of the N levels. Every increment of 40 kg N ha^{-1} from 0 to 120 kg N ha^{-1} increased the total N uptake by 49.55, 34.30 and 27.17% total P uptake by 40.33, 27.06 and 20.32% and total K uptake by 32.43, 20.70 and 17.25%, respectively.

Singh and Kumar (2003) conducted a field experiment and recorded the application of slow release fertilizers (USG), biogas slurry and blue green algae + prilled urea (PU) significantly increased grain and straw yield, nitrogen uptake, nitrogen use efficiency, and nitrogen recovery in rice. The highest grain yield, nitrogen recovery was recorded with the application of USG.

2.5. Effect of nitrogen on biological yield and harvest index

Iqbal (2011) carried out an experiment on determination of the effects of five fertilizer application rates on vertical leaching from 30 cm and 60 cm soil layers found that during paddy growth, nitrogen losses from different nitrogen treatments varied 2.82-5.07% application of the urea compared to USG.

Gaudin (2012) carried out an experiment on the kinetics of ammonia disappearance from deep-placed urea supergranules (USG) in transplanted rice: the effects of deep placement USG application and PU fertilizer. He found that ammonia disappearance from the placement site is faster for the second application, and it appears that the rice roots took up ammonia at a higher concentration: 20 mM for the second application versus 10 mM for the first application.

Mishra *et al.* (1999) reported that apparent N recovery in rice also increased from 21% for PU to 40% for USG. Here Rice showed a greater response to N upon USG placement than split application of PU.

Sarker *et al.* (2001) obtained the nitrogen response of a Japonica and an Indica rice variety with different nitrogen levels viz. 0, 40, 80 and 120 kg N ha^{-1}. They observed that application of nitrogen increased grain and straw yields significantly but harvest index was not increased significantly.

Dwivedi (1997) noticed that application of nitrogen significantly increased the growth yield and yield components grain yield, straw yield as well as harvest index with 60 kg N /ha.

CHAPTER III

MATERIALS AND METHODS

An experiment was conducted at the research field in Sher-e-Bangla Agricultural University(SAU),Dhaka-1207,during the boro season of 2015-2016 to study on the performance of growth variability ,yield potentialities and nutrient management practices of rice as influenced by different urea super granule applicators. This chapter deals with a brief description on experimental period, experimental site, climate, soil, and land preparation, crop, layout of the experimental design, intercultural operations, data recording and their analyses. Details of materials and methods used in this experiment are given below:

3.1 Experimental period

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the boro season of January 2016 to April 2016.

3.2 Description of the experimental site

3.2.1 Geographical location

The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.2 meter above sea level. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Madhupur Tract", AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.2 Climate

The experimental site under the sub-tropical climate that is characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during Rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix II.

3.2.3 Soil

The soil of experimental site belongs to the general soil type, deep red brown terrace soil under Tejgaon series .Top soils silty clay loam in texture, olive gray with common fine to medium distinct dark yellowish brown mottles. soil pH was 5.7 and had organic matter 1.12%.The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected before transplanting the rice seedling. The collected soil was air dried, grind and passed through 2 mm sieve and analyzed for both physical and chemical properties in the laboratory of SAU. The properties studied included pH, organic matter, total N available P and exchangeable K .The soil was analyzed following standard methods.

3.3 Experimental details

3.3.1 Crop/planting material

BRRI Dhan-28 was used as test crop.

3.3.2 Treatments

One factors of treatments included in the experiment were as follows:

T_0 = Control

T_1 = Application of urea briquette by hand placement

T_2=Application of urea briquette by battery- powered applicator

T_3=Application of urea briquette by BRRI applicator

T_4=Application of urea briquette by injector applicator

T_5=Application of urea briquette by push- type applicator

T_6=Application of prilled urea by broadcast method

3.3.3 Experimental design

Design: Randomized Complete Block Design (RCBD)

Factor: 1

Treatment: 7

Replication: 3

Total number of plots: 21

Plot size: 12 m × 2.4 m

Block to block distance: 1 m

Plot to plot distance: 0.5 m

3.4 Crop Management

3.4.1 Seed Collection

Healthy and vigorous seeds of BRRI dhan 28 from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur.

3.4.2 Sprouting of Seed

The seeds were soaked in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and became suitable for sowing after 72 hours.

3.4.3 Raising of Seedlings

Seedlings were raised on a high land in the south-east side of the Research farm of SAU. Seeds were sown in the seedbed on December 20, 2015 for raising seedlings. The nursery beds were prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. Proper care was taken to raise seedlings in the nursery bed. The beds were kept weed free throughout the period of seedling raised.

3.4.4 Preparation of Experimental Land

The experimental field was first ploughed on January 15, 2016 with the help of a tractor drawn rotary plough. Later on January 20, 2016 the land was irrigated and prepared by three successive ploughing and cross ploughing with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on January 21, 2016 according to experimental specification.

3.4.5 Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was sub-divided into seven unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 21 .The unit plot size was 12m×2.4m.Block to block distance was 1m and plot to plot distance was 0.5 m. The layout of the experiment has been shown in Fig 1.

Here, T_0 = Control

T_1 = Application of urea briquette by hand placement

T_2 = Application of urea briquette by battery- powered applicator

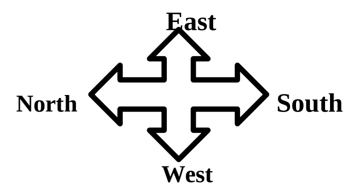
T_3 = Application of urea briquette by BRRI applicator

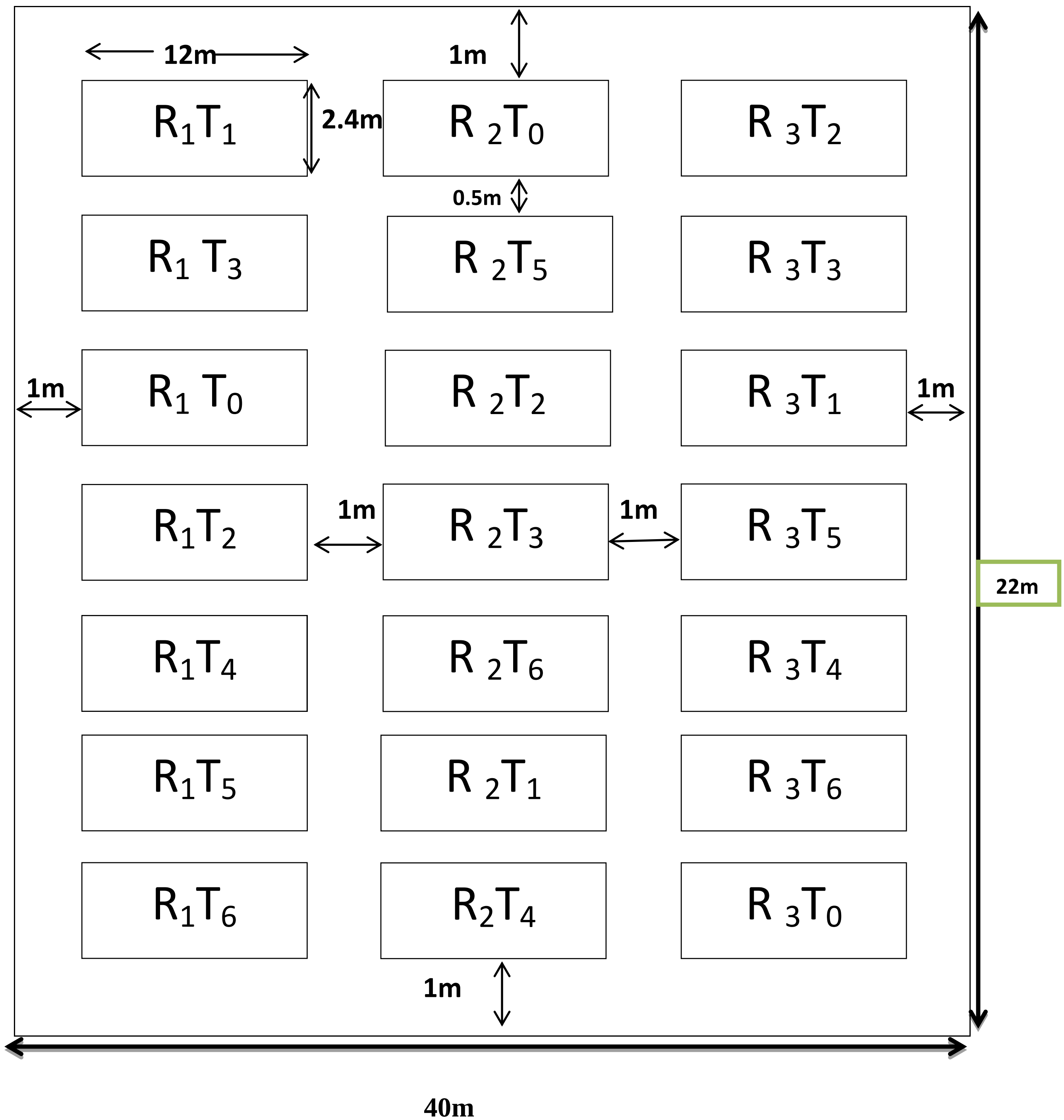
T_4 = Application of urea briquette by injector applicator

T_5 = Application of urea briquette by push- type applicator

T_6 = Application of prilled urea by broadcast method

Fig 1: Layout of the experiment





3.4.6 The uprooting of seedlings

Thirty two days old seedlings were uprooted carefully on January 23, 2016 and were kept in soft mud in shade**.** The seedbeds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots.

3.4.7 Transplanting of seedlings

On 23 January , 2016, thirty two days old seedlings were transplanted in the experiment field keeping plant to plant distance 20 cm and row to row distance 20 cm. Gap filling was made up to 7 days after transplanting to maintain similar plant population density for each plot.

3.4.8 Guti urea placement

Thirty two days old seedlings were transplanted in the experiment field keeping plant to plant distance 20 cm and row to row distance 20 cm. Guti urea were placed at 7 DAT. One supergranule was placed in the middle of each four hills at 6–10 cm soil depth using different applicators. Use modified 20 cm × 20 cm spacing to facilitate efficient placement of USG by hand or machine. In case of BRRI applicator, push- type applicator and battery powered applicator, the skids of the applicator were placed between rows of rice plants keeping two rows of rice plants between the skids. Half of the fertilizer hoppers were filled with Urea Super Granule (USG).The applicator was then pushed forward manually or battery power. This made the cage wheel and the metering devices rotated. During rotation of the metering devices, it carried USG into the pockets and delivered them to the furrow openers. During forward movement of the applicator, the skids helped float the machine. The applicator dropped the USG at 20 cm row spacing and at 6-10 cm depth.

3.4.9 Soil and Water Sample collection

Water samples were collected from each plot after guti placement during 1-7 days. At the same time of water sample collection, soil samples were collected from the surrounding soil area where guti was placed. Soil samples were extracted by KCl solution for extracting ammonium and then ammonium concentration in water and extract were determined by colour development.

3.4.9.1 Determination of Ammonium Nitrogen (NH_4^+-N) by Phenolhypochloride method

Reagents required

1. Phenol

2. Ethyl alcohol

3. Sodium nitroprusside

4. Sodium hypochloride solution

5. Trisodium citrate

6. NaOH

Reagents Preparation

1. Phenol-alcohol solution

10 gm phenol in 100 ml ethyl alcohol

2. Na nitroprusside

0.5% solution in distilled water (0.5 gm Na nitroprusside in 100 ml DW)

3. Alkaline solution

100 gm trisodium citrate + 5.0 gm NaOH ----Volume 500 ml with distilled water

4. Hypochloride solution

1.5 N solution (It is readily available by bought)

5. Oxidizing solution

100 ml alkaline solution + 25 ml hypochloride solution i.e.is the one fourth of alkaline solution.

6. Procedure of Phenolhypochloride method

25 ml water or soil extract was taken in volumetric flask. Then 2 ml phenol solution was added and kept for 5 minutes. Then 2 ml Na-nitroprusside solution was added and kept for 5 minutes. Then 5 mL oxidizing solution was added and mixed thoroughly after each addition. After mixing, volume was made upto the mark and the solution was kept for 1 hour for colour development and measured absorbance at 640 nm wave length.

7. Standard solution

0.4717 g ammonium sulphate was taken for preparing the 100 ppm ammonium solution. Then 0.1, 0.2, 0.3, 0.4, 0.5 ppm solutions were prepared by taking 2.5, 5, 7.5, 10 ,15 ml solutions respectively. Then colour developed by following the procedure of Phenolhypochloride method and measured absorbance at 640 nm wave length.

3.4.10 Inter-cultural operations

After one week of transplanting gap filling were done to maintain the constant population number. After transplanting the nursery seedlings gap filling was done whenever it was necessary using the seedling from the previous source.

3.4.10.1 Weeding

Weed infestation was a severe problem during the early stage of crop establishment. The experimental plots were infested with some common weeds. To minimize weed infestation, manual weeding through hand pulling was done three times during entire growing season.

3.4.10.2 Irrigation and drainage

Proper irrigations were provided to the plots when necessary during the growing period of rice crop. It was allowed to dry out water for 2 to 4 days during tillering. From panicle initiation (PI) to hard drought stage, a thin layer of water (2-3) was kept on the plots. Again water was drained from the plots during ripening stage.

3.4.10.3 Plant protection measure

Plants were infested with leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by applying Darsbarn @ 10 ml/10 liter of water on February 17,2016 and Rice hispa (*Dicladispa armig-era*) by Malathion 57 EC @1L/ha on February 27, 2016.During the grain filling period crop was protected from rice bug (*Leptocorisa acuta)* during the grain filling period by Diazinon 60 EC@1.7L/ha. Plants were infested with rice stem borer (*Scirphophaga incertolusura*) controlled by Furadan 5G. Crop was protected from birds during the grain filling period. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.11 Harvesting and postharvest processing

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting of BRRI dhan 28 was done on April 23, 2016. 12 m × 2.4m(28.8 m^2) area of each plot were harvested for collecting data on crop yield. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The crops were threshed by pedal thresher and then grains were cleaned. The grain and straw weights for each plot were recorded after proper sun drying and then converted into ton /hectare. The grain yield was adjusted at 14% moisture level.

3.5 Collection of Plant Samples

Five hills were randomly selected from each plot at maturity to record the yield contributing characters.

3.6 Recording of data

Data were collected on the following parameters at harvest:

1. Number of effective tillers/hill

2. Number of non-effective tillers /hill

3. Plant height (cm)

4. Panicle length (cm)

5.1000 grain weight (gm)

6. Straw yield (t/ha)

7. Grain yield (t/ha)

3.7 Procedure of recording data

A brief outline on data recording procedure followed during the study is given below:

3.7.1 Growth characters

3.7.1.1 Plant height (cm)

The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of the flag leaf after heading. From each plot, 10 plants of 5 hills were measured and averaged.

3.7.1.2. Tiller no/hill

Number of effective and non -effective tillers per hill was counted after harvest.

3.7.1.3 Yield and yield components

The sample plants of 5 hills were harvested randomly from each plot and tagged them separately. Data on yield components were collected from the sample plants of each plot.

3.7.1.4 Total tillers number/hill

Tillers with at least one visible leaf were counted. It included both effective and non-effective tillers.

3.7.1.5 Number of effective tillers /hill

Tillers having panicles which had at least one grain were considered as effective tillers.

3.7.1.6 Number of non-effective tillers/ hill

The panicle which had no grain was recorded as non-effective tillers.

3.7.1.7 Panicle length (cm)

The measurement of panicle length was taken from basal node of the rachis to apex of each panicle and expressed in centimeter (cm). Each observation was an average of 5 hills.

3.7.1.8 Weight of 1000-grain (gm)

One thousand clean dried grains from the seed stock of each plot were counted separately and weighed by using a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

3.7.1.9 Grain yield

Grains obtained from the $12m \times 2.4\ m$ areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 14% moisture level. Dry weight of grams of each plot was converted into ton/ ha.

3.7.1.10 Straw yield:

Straw obtained from the $12m \times 2.4\ m$ area of each plot were sun dried, cleaned, weighed separately and finally converted into ton/ha.

3.7.2.10 Biological yield

Grain yield and straw yield were together regarded as biological yield. Biological yield was calculated with the following formula:

Biological yield (t /ha) = Grain yield (t /ha) + Straw yield (t/ ha)

3.7.2.11 Harvest index

It is the ratio of economic yield to biological yield and was calculated with the following formula:

Harvest Index (%) = (Grain yield/Biological yield) × 100

3.8 Statistical analysis of the data

The analysis of variance for different crop characters as well as for different nutrient concentrations of the treatments were made and the mean differences were judged at 5% level of probability by using Duncan's Multiple Range Test (DMRT) with a computer operated program named MSTAT-C.

CHAPTER IV

RESULT AND DISCUSSION

Result obtained from the study of prilled urea and urea briquettes application methods on growth and yield of boro rice have been presented and discussed in this chapter. Treatments effect of urea and urea briquettes application methods on all the studied parameters have been presented in various tables and figures and discussed below under the following sub-headings.

4.1. Growth Performance

4.1.1 Non Effective Tiller Number/Hill

Number of non-effective tillers per hill of boro rice was not significantly influenced by the application method of prilled urea and urea briquettes (Table 1).At harvest the highest non effective tiller number(0.74) was recorded in the treatment T_6 (Application of prilled urea by Broadcast method).The lowest non effective tiller number per hill was found in T_3 treatment (Application of urea briquette by BRRI applicator).

Table 1. Effect of nitrogen sources and application methods on number effective tillers / hill of boro rice

Treatment	Non effective tillers/hill
T_0	0.47
T_1	0.60
T_2	0.20
T_3	0.20
T_4	0.27
T_5	0.47
T_6	0.74
LSD value$_{(0.05)}$	NS
CV (%)	111.69

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.2 Effective Tiller Number /Hill

Number of effective tillers / hill was significantly affected due to different nitrogen sources and application methods (Table 2). Effective tillers number of boro rice was significantly influenced by the application methods of prilled urea and urea briquettes. At harvest the highest number of effective tillers (17.20) was recorded in the treatment T_3 (Application of urea briquette by BRRI applicator) which was statistically similar to T_5 (Application of urea briquette by Push- type applicator) and the lowest effective tillers number was found in T_0 treatment (control).When application of urea briquette by BRRI applicator, plant accumulated higher amount of nitrogen and the effective tiller number of plant increased.

Table2. Effect of nitrogen sources and application methods on number effective tillers / hill of boro rice

Treatment	Effective tiller no/hill
T_0	8.67 c
T_1	15.07 ab
T_2	11.87 b
T_3	17.20 a
T_4	13.67 b
T_5	17.13 a
T_6	11.67 b
$LSD_{(0.05)}$	3.263
CV (%)	14.07

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.3 Plant Height

Plant height is an important morphological character that acts as a potent indicator of availability of growth resources in its vicinity. Effect of nitrogen source and methods of application showed a significant variation on plant height for all growth stages (Table 3). Plant height of boro rice was significantly influenced by nitrogen sources and application methods (Table 3). At harvest the highest plant height (98.55 cm) was recorded from treatment T_1 (Application of urea briquette by hand placement) which was statistically similar to T_3 (Application of urea briquette by BRRI applicator) and the lowest plant height (74cm) was found in T_0 treatment (control).

Table 3. Effect of nitrogen sources and methods of application on plant height of boro rice

Treatment	Plant height (cm)
T_0	74 c
T_1	98.55 a
T_2	86.30 b
T_3	96.87 a
T_4	94.57 ab
T_5	90.03 ab
T_6	89.50 ab
$LSD_{(0.05)}$	9.038
CV (%)	5.65

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.4. Panicle Length

Panicle length of boro rice was significantly influenced by nitrogen sources and application methods (Table 4).At harvest the highest panicle length(22.73 cm) was recorded in the treatment T_1 (Application of urea briquette by hand placement) which was statistically similar to T_6(Application of prilled urea by broadcast method) ,T_5(Application of urea briquette by Push- type applicator) and T_3 (Application of urea briquette by BRRI applicator) and the lowest panicle length (19.5cm) was found in T_0 treatment (control).

Table 4.Effect of nitrogen sources and methods of application on panicle length of boro rice:

Treatment	Penical length(cm)
T_0	19.5 c
T_1	22.73 a
T_2	19.97 b
T_3	20.77 ab
T_4	20.63 b
T_5	21.22 ab
T_6	21.30 ab
$LSD_{(0.05)}$	1.850
CV (%)	4.98

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.5 1000 Grain Weight

The 1000 grain weight of boro rice was significantly influenced by nitrogen sources and application methods (Table 5).The highest 1000 grain weight was recorded in the treatment T_3 (Application of urea briquette by BRRI applicator) which was statistically similar to T_1(Application of urea briquette by hand placement), T_6(Application of prilled urea by broadcast method) and the lowest 1000 grain weight (20.66) was found in T_0 treatment(control). The result fairly agreed with the findings of Mohaddesi *et al*. (2011) that 1000 grain weight had significant effect with increasing nitrogen levels but Rahman (2003) and Azad *et al.* (1995) found that the level of nitrogen didn't influence the weight of 1000-grain weight significantly which is dissimilar with this findings.

Table 5. Effect of nitrogen sources and methods of application on 1000 grain weight of boro rice

Treatment	1000 grain weight(gm)
T_0	20.66 d
T_1	22.67 ab
T_2	21.67 bc
T_3	23.33 a
T_4	21.33 c
T_5	21.67 bc
T_6	22.67 ab
$LSD_{(0.05)}$	1.176
CV (%)	2.98

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.6 Straw Yield

Straw yield of boro rice was significantly influenced by nitrogen sources and application methods (Table 6).Highest straw yield (7.283 t/ha) was obtained in the treatment $T_{3,}$ (Application of urea briquette by BRRI applicator) which was statistically similar to T_4(Application of urea briquette by injector applicator) and the lowest straw yield (3.996 t/ha) was found in T_0 treatment (control).When application of urea briquette by BRRI applicator plant accumulated higher amount of nitrogen and the biomass of plant increased. Elbadry *et al.* (2004), Meena *et al.* (2003) and El-Rewainy (2002) observed similar view on straw yield due to nitrogen application.

Table 6. Effect of nitrogen sources and methods of application on straw yield of boro rice

Treatment	Straw yield(t/ha)
T_0	3.996 c
T_1	6.317 ab
T_2	4.800 b
T_3	7.283 a
T_4	7.083 a
T_5	6.447 ab
T_6	6.217 ab

$LSD_{(0.05)}$	1.639
CV (%)	15.30

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.7 Grain yield

Grain yield of boro rice was significantly influenced by nitrogen sources and application methods (Table 7).The highest grain yield(5.817 t/ha) was obtained in the treatment T_3(Application of urea briquette by BRRI applicator) which was statistically similar to T_4(Application of urea briquette by injector type applicator),T_1(Application of urea briquettes by hand placement),T_5 (Application of urea briquette by push type applicator) .The lowest grain yield(2.39 t/ha) was found in T_0 treatment (control).

Table 7. Effect of nitrogen sources and methods of application on grain yield of boro rice

Treatment	**Grain yield(t/ha)**
T_0	2.39 c
T_1	5.493 a
T_2	4.520 b
T_3	5.817 a
T_4	5.747 a
T_5	5.277 a

T_6	4.280 b
$LSD_{(0.05)}$	0.7071
CV (%)	8.30

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.8 Biological Yield

Biological yield differed significantly due to the different sources of nitrogen and methods of application (Table 8). Application of treatment T_3 (13.10 t/ha) produced the highest biological yield (13.10 ton/ha)) than treatment T_4 (12.83 t/ha) and T_1 (11.81 t/ha) of nitrogen sources and application methods and the lowest biological yield (6.39 t/ha) was found in T_0 (control). The result agreed with the findings of Ahmed *et al.* (2005) who observed the significant effect of nitrogen on biological yield (ton/ ha) of rice.

Table 8. Effect of nitrogen sources and methods of application on biological yield of boro rice

Treatment	Biological yield (t/ha)
T_0	6.39 d
T_1	11.81 ab
T_2	9.320 c
T_3	13.10 a
T_4	12.83 a
T_5	11.72 ab

T_6	10.50 bc
$LSD_{(0.05)}$	1.809
CV (%)	9.41

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.1.9 Harvest Index

Effect of nitrogen sources and methods of application exerted significant variation on harvest index (Table 9). Harvest index was highest at T_2 treatment (48.80%) Statistically similar harvest index was found from the application of treatment T_1 (46.52) and T_5(45.08%). The lowest harvest index (38.38%) was recorded in T_0 (control).

Table 9. Effect of nitrogen sources and methods of application on harvest index of boro rice

Treatment	Harvest Index (%)
T_0	38.38 b
T_1	46.52 a
T_2	48.80 a
T_3	44.53 a
T_4	44.91 a
T_5	45.08 a
T_6	40.92 a

$LSD_{(0.05)}$	9.070
CV (%)	11.55

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

4.2 Nutrient Parameter

Prilled urea and urea briquettes were placed by different applicator in the rice field at 7th DAT. Then NH_4 concentrations in soil and water samples were determined during 7 days after placement of prilled and urea briquettes in rice field. The ammonium nitrogen (NH_4^+-N) determined by phenolhypochloride method. Ammonium nitrogen was significantly affected due to different nitrogen sources and application methods.

4.2.1 Day 1

Ammonium concentration in water

Prilled urea and urea briquettes were placed by different applicators in the rice field at 7th days after rice seedling transplanting. Ammonium concentration in water from boro rice field was determined after placement of prilled and urea briquettes in rice field. The ammonium nitrogen (NH_4^+-N) determined by phenolhypochloride method .Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table10). The highest amount of ammonium was recorded in the treatment T_6 (Application of prilled urea by broadcast method) which was statistically similar to T_2 (Application of urea briquette by battery power applicator) and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by prilled urea broadcast method, plant accumulated higher amount of nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 10). The highest amount of soil ammonium was recorded in the treatment T_1 (Application of Urea brequettes by hand placement method) which was statistically similar to T_3 and T_5 and the lowest ammonium was recorded in T_0 treatment (control).When urea briquettes was placed by hand placement method, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Table 10. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatment	Paddy field water NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	0.89 d	40.7 b
T_1	2.04 cd	86.77 a
T_2	4.64 ab	62.27 a
T_3	2.71 bc	83.63 a
T_4	2.20 cd	73.93 a
T_5	4.08 bc	78.40 a
T_6	6.47 a	65.77 a
$LSD_{(0.05)}$	2.187	31.88
CV (%)	26.66	18.09

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.2.2 Day 2

Ammonium concentration in water

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 11). The highest amount of ammonium was recorded in the treatment T_6 (Application of prilled urea by broadcast method) which was statistically similar to T_2(Application of urea briquette by battery power push type applicator) $T_{5,}T_3$ and the lowest ammonium was recorded in T_0 treatment (control) which was statistically similar to T_1.When prilled urea was placed in the soil by broadcast method, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table11). The highest amount of soil ammonium was recorded in the treatment T_3 (Application of urea briquettes by BRRI applicator) which was statistically similar to T_5 (Application of urea briquette by push type applicator) and the lowest ammonium was recorded in T_0 treatment (control).When urea briquette was placed in the soil by BRRI applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Table 11. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatment	Floodwater NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	1.07 c	44.40 d
T_1	2.54 bc	85.03 bc
T_2	6.19 ab	78.03 c

T_3	5.05 ab	154.30 a
T_4	3.25 abc	101.50 bc
T_5	5.46 ab	120.50 ab
T_6	6.88 a	72.57 c
$LSD_{(0.05)}$	3.373	37.69
CV (%)	31.27%	16.13%

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.2.3 Day 3

Ammonium concentration in water

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 12). The highest amount of ammonium was recorded in the treatment T_2 (Application of urea briquette by battery powered applicator) which was statistically similar to T_5 and T_6 and the lowest ammonium was recorded in T_0 treatment (control).When urea briquette was placed in the soil by battery powered applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 12). The highest amount of soil ammonium was recorded in the treatment T_3 (Application of urea briquette by BRRI applicator) which was statistically similar to $T_{2,}$ T_1 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by BRRI applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant

Table 12. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatment	Paddy field water NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	1.29 c	46.40 b
T_1	3.26 bc	112.30 a
T_2	8.57 a	114.60 a
T_3	4.63 abc	120.30 a
T_4	2.72 bc	91.86 a
T_5	7.36 ab	102.6 a
T_6	7.19 ab	110.9 a
$LSD_{(0.05)}$	4.837	43.01
CV (%)	39.21	17.34

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.2.4 Day 4

Ammonium concentration in water

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 13). The highest amount of ammonium was recorded in the treatment T_6(Application of prilled urea by broadcast method) which was statistically similar to T_2 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by prilled urea broadcast method, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 13). The highest amount of soil ammonium was recorded in the treatment T_3 (Application of urea briquette by BRRI applicator) which was statistically similar to $T_{2,}$ T_5 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by BRRI applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Table 13. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatment	Paddy field water NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	0.93 c	42.30 b
T_1	4.10 b	82.97 a
T_2	8.51 a	92.77 a
T_3	4.81 b	101.5 a
T_4	2.81 b	82.43 a
T_5	4.88 b	92.73 a
T_6	9.17 a	77.03 a
$LSD_{(0.05)}$	2.387	32.17
CV (%)	19.05	15.75

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.10.5 Day 5

Ammonium concentration in water

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 14).The highest amount of ammonium was recorded in the treatment T_2(Application of urea briquettes by battery powered applicator) and the lowest ammonium was recorded in T_0 treatment (control plot).When urea was placed in the soil by battery powered applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 14).The highest amount of soil ammonium was recorded in the treatment T_3(Application of urea briquette by BRRI applicator) which was statistically similar to T_5 and T_1 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by BRRI applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Table 14. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatmen	Paddy field water NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	0.86 d	40.4 c
T_1	4.14 c	103.9 a
T_2	8.85 a	93.43 ab
T_3	4.95 bc	116.0 a
T_4	2.81 c	91.90 ab
T_5	4.88 bc	111.5 a
T_6	6.84 b	66.27 b

$LSD_{(0.05)}$	1.994	30.88
CV (%)	16.77	13.83

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.10.6 Day 6

Ammonium concentration in water

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 15). The highest amount of ammonium was recorded in the treatment T_3(Application of urea briquettes by BRRI applicator) which was statistically similar to T_6 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by BRRI applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 15). The highest amount of soil ammonium was recorded in the treatment T_2(Application of urea briquette by battery powered applicator) which was statistically similar to T_3 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by battery powered applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Table 15. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatment	Paddy field water NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	0.73 d	39.60 c
T_1	2.34 c	84.77 b
T_2	4.83 b	109.2 a
T_3	6.20 a	108.8 a
T_4	1.05 d	71.93 b
T_5	2.45 c	90.00 ab
T_6	5.56 ab	88.07 ab
$LSD_{(0.05)}$	1.124	21.97
CV (%)	13.54	10.33

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.10.7 Day 7

Ammonium concentration in water

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 16). The highest amount of ammonium was recorded in the treatment T_2 (Application of urea briquettes by battery powered applicator) which was similar to T_6 and the lowest ammonium was recorded in T_0 treatment (control) which was similar to T_4.When urea was placed in the soil by battery powered applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Ammonium concentration in soil

Ammonium nitrogen was significantly affected due to different nitrogen sources and methods of application (Table 16). The highest amount of soil ammonium was recorded in the treatment T_2 (Application of urea briquette by battery powered applicator) which was statistically similar to T_6 T_5, T_4 and the lowest ammonium was recorded in T_0 treatment (control).When urea was placed in the soil by battery powered applicator, plant accumulated higher amount of ammonium nitrogen and increased the growth and development of plant.

Table 16. Effect of nitrogen sources and methods of application on soil and soil solution ammonium in boro rice field

Treatment	Paddy field water NH_4 (ppm)	Soil NH_4 conc(mg/kg)
T_0	0.72 c	39.90 b
T_1	1.84 b	96.00 a
T_2	4.44 a	111.1 a
T_3	1.55 b	99.93 a
T_4	1.23 bc	100.2 a
T_5	1.42 b	103.9 a
T_6	3.77 a	106.4 a
$LSD_{(0.05)}$	1.115	22.45
CV (%)	20.68	9.53

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance.

4.3 Correlation between soil ammonium and grain yield

Ammoniun concentration in soil

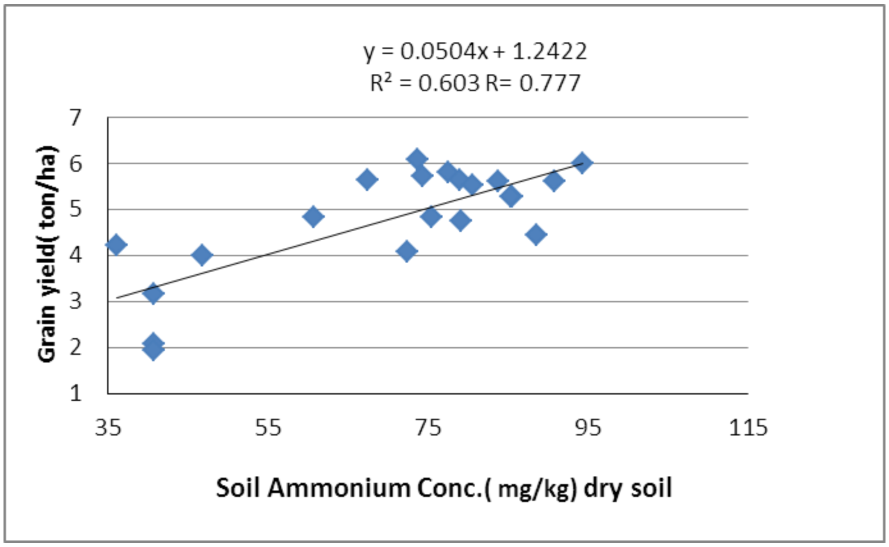


Fig 2: Relationship between grain yield and soil ammonium concentration in 1 st DAT

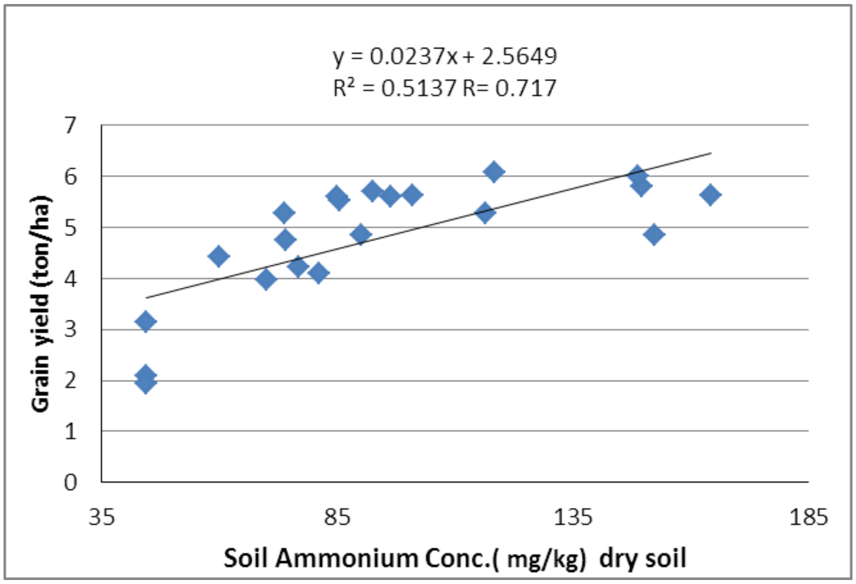


Fig 3: Relationship between grain yield and soil ammonium concentration in 2nd DAT

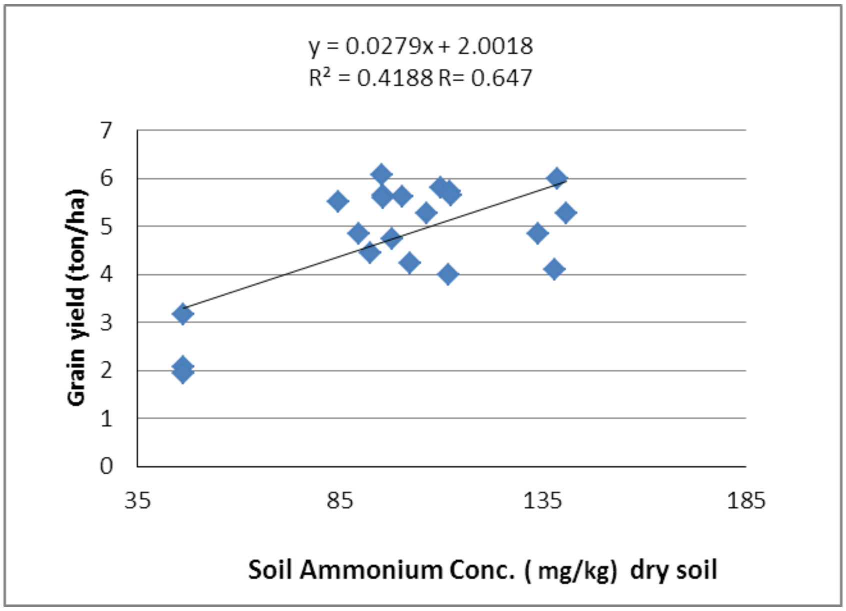


Fig 4: Relationship between grain yield and soil ammonium concentration in 3rd DAT

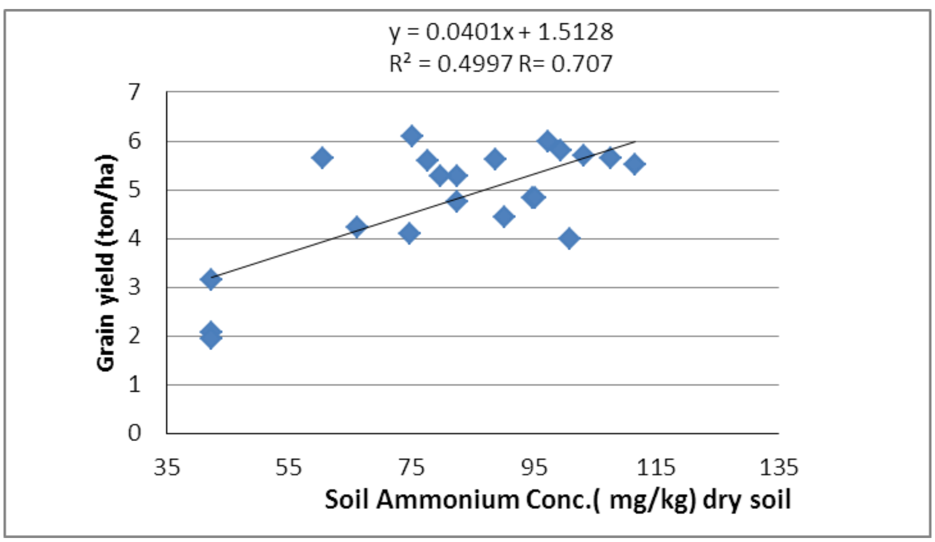


Fig 5: Relationship between grain yield and soil ammonium concentration in 4th DAT

In order to examine the relationship between yield and soil ammonium concentration a correlation analysis was done.It appears that grain yield was significantly correlated with the soil ammonium concentration of 1st DAT (R=0.77**). Similar significant correlations were observed between the grain yield and soil ammonium concentrations of 2nd DAT(R= 0.72**),3rd DAT(R= 0.65**) , 4th DAT(R=0.71**). Considering the above observation of the present experiment correlation analysis indicate that the rice yield was significantly correlated with the soil ammonium concentration.

CHAPTER V

SUMMARY AND CONCLUSION

The present research work was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2015 to April, 2016 to study the feasibility of application of urea and urea briquettes by using different urea deep placement applicator on growth, yield components and yield performance in boro rice. The experiment comprised 7 different treatments of different urea deep placement method.

The one factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and analysis was done by MSTST-C package program whereas means were adjusted by LSD at 5% level of probability.

Results showed that a significant influence was observed among the treatments regarding all of the parameters observed. The collected data were statistically analyzed for evaluation of the treatment effect. The size of unit plot was 28.8 m^2 (12m× 2.4 m) while block to block distance were 1.0m and plot to plot distance 0.50 m. The total number of plots were 21. The row to row and plant to plant distances were 20 cm. In case of the effect of urea application method, effective and non-effective tiller number, plant height, panicle length, 1000 grain weight, straw yield, grain yield were significantly affected due to the effect of different urea application method. Significant difference was observed in producing non-effective tillers/ hill due to prill urea and urea briquettes application method. The highest number of non-effective tillers number/hill (0.74) was counted from T_6 treatment. The lowest non-effective tiller number/hill (2.0) was T_3 treatment. At harvest the highest effective tiller number (17.20) was recorded in the treatment T_3 (Application of urea briquettes by BRRI applicator). The lowest effective tiller number (8.67) was T_0 treatment (control). At harvest the highest plant height (98.55 cm) was recorded from treatment T_1 (Application of urea briquettes by hand placement). The lowest plant height (74cm) was T_0 treatment (control).

The highest Panicle length (22.73 cm) was recorded in the treatment T_1 (Application of urea briquettes by hand placement. The lowest panicle length (19.5 cm) was T_0 treatment (control).The highest 1000 grain weight (23.33 gm) was recorded in the treatment T_3 (Application of USG by BRRI applicator. The lowest 1000 grain weight (20.66 gm) was T_0 treatment (control). Highest straw yield (7.283 t /ha) was recorded in the treatment $T_{3,}$ (Application of urea briquette by injector type applicator). The lowest straw yield (3.996 t/ha) was T_0 treatment (control). The highest grain yield (5.817 t/ha) was obtained in the treatment T_3 (Application of urea briquitte by BRRI applicator). The lowest grain yield (2.39 t/ha) was T_0 treatment (control). Prilled urea and urea briquette was placed by different applicator in the rice field 7^{th} days after rice seedling transplanting. Ammonium concentrations in soil and water samples from boro rice field were recorded after placement of prilled urea and urea briquettes in rice field.The ammonium nitrogen (NH_4^+-N) determined by phenolhypochloride method. The application of T_3 treatment showed the highest grain yield (5.82 t /ha) and straw yield (7.28 t/ha) than any other sources of nitrogen and methods of application. Experimental results showed that nitrogen sources and application methods had significant effect on NH_4^+ concentration in standing water of experimental peddy soil. The higher ammonium concentrations (9.17 ppm) were found in the water of T_6 (Application of prilled urea by broadcast method) treatment during 1-7 days of water samples. The higher soil ammonium concentrations(120.3 mg/kg dry soil) were observed in the treatment of T_3 (Application of urea briquette by BRRI applicator) during 1-7 days of collected soil samples.Findings revealed that when guti was placed with BRRI applicator showed the superiority over other sources of nitrogen and application methods to produce higher grain yield of boro rice.

From the correlation analysis,the rice yield was significantly correlated with the soil ammonium concentration.

Reviewing above the results of the present study, it might be concluded that,

1. T_3 treatment (Application of urea briquettes by BRRI applicator) showed the superiority over other nitrogen sources and application methods to produce higher grain yield of rice.

2. Sources and application methods of nitrogen as urea brequette showed the superiority over prilled urea.

3. T_3 (Application of urea briquettes by BRRI applicator) showed the higher performance than other tested application method of urea deep placement.

From the above results, it may be concluded that application of urea briquette by BRRI applicator showed the better performance on growth and yield of boro rice which is closely similar to T_4, T_1 and T_5 treatments. So, considering the above observation T_3 may be possible to use in replacing with other urea deep placement applicator which will reduce production cost and increase boro rice yield.

Recommendations:

Considering the above observation of the present experiment, further studies in the following areas may be suggested.

1. The application of urea briquette by BRRI applicator which would incur least cost along with soil improvement might be suggested to be followed in boro rice production.
2. Expansion of different methods of urea deep placement study to know the growth and yield performance of boro rice in different agro-ecological zones (AEZ) of Bangladesh for regional variability.
3. Innovations to application of urea and urea briquettes deep placement applicator to confirm the replacement prilled urea broadcast and urea brequettes by hand placement.

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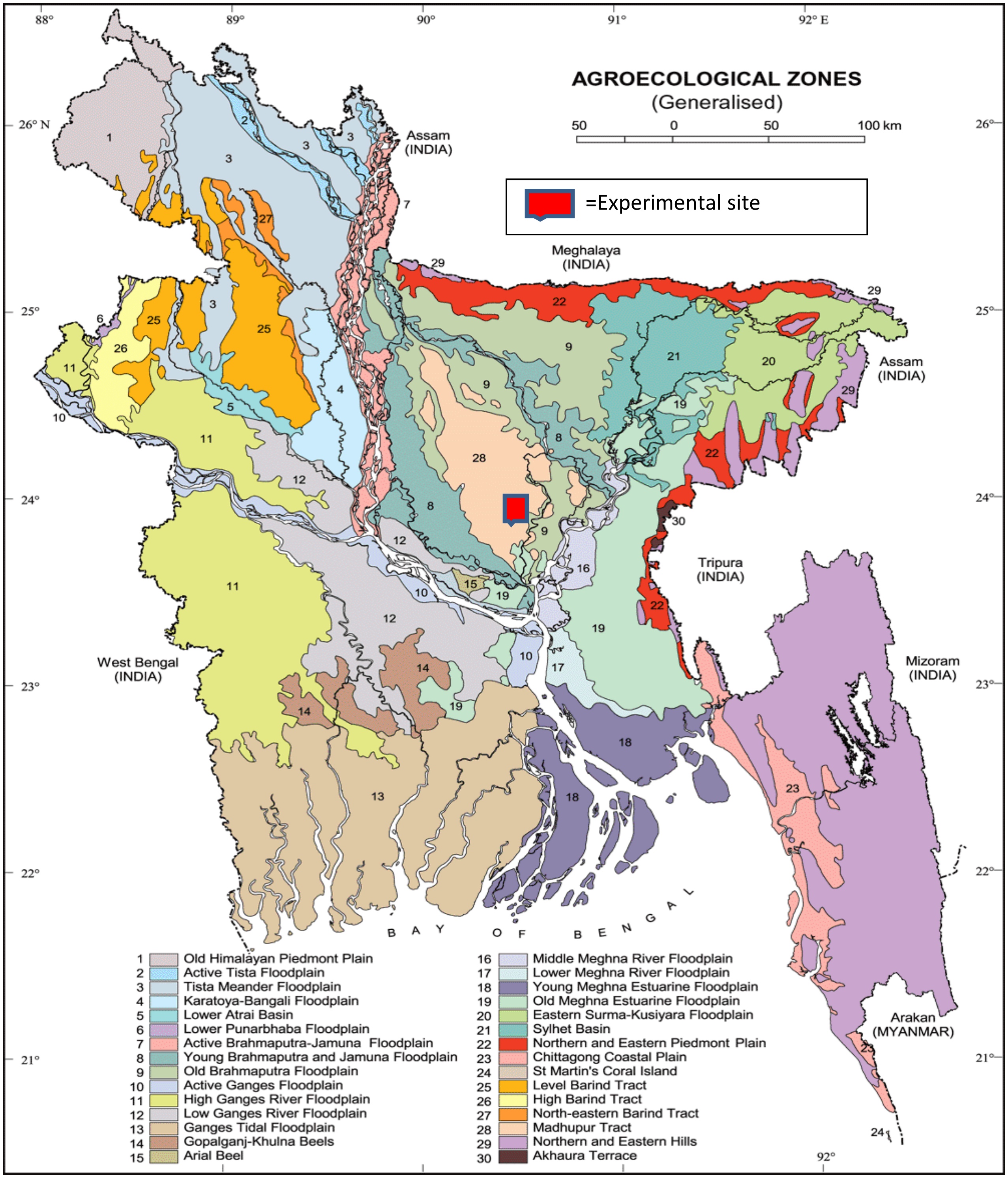
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Appendix II. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from November 2015 to April 2016

Months	*Air temperature (^{0}C)		*Relative humidity (%)	Total rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2015	25.82	16.04	78	00	6.8
December, 2015	22.40	13.50	74	00	6.3
January, 2016	24.50	12.40	68	00	5.7
February, 2016	27.10	16.70	67	30	6.7
March, 2016	31.40	19.60	54	11	8.2
April,2016	33.50	22.60	61	160.6	9.3

*Monthly average, *Source: Bangladesh Meteorological Department (Climate & Weather division) Agargoan,Dhaka-1207

Appendix III. ANOVA showing the mean square values of non-effective tiller no/hill, effective tiller no/hill, plant height, panicle length,1000 grain weight of boro rice influenced by source of nitrogen and application methods.

Sources of variation	Degrees of freedom	Mean square values at harvest				
		Non effective tiller no/hill	Effective tiller no/hill	Plant height(cm)	Panicle length(cm)	1000 Grain yield(gm)
Replication	**2**	**0.265**	**4.368**	**40.822**	**0.251**	**2.714**
Treatment	**6**	**0.126**	**22.102**	**205.522**	**3.267***	**1.651***
Error	**12**	**0.209**	**3.365**	**25.813**	**1.081**	**0.437**

*= Significant at 5% level of probability

Appendix IV. ANOVA showing the mean square values of straw yield,grain yield,biological yield,harvest index of boro rice influenced by nitrogen source and application methods

Sources of variation	Degrees of freedom	Mean square values at harvest			
		Straw yield (t/ha)	Grain yield (t/ha)	Biological Yield(t/ha)	Harvest Index(%)
Replication	**2**	**0.798**	**0.108**	**0.333**	**33.172**
Treatment	**6**	**4.309**	**4.397**	**16.521**	**36.286***
Error	**12**	**0.849**	**0.158**	**1.034**	**25.995**

*= Significant at 5% level of probability

Appendix V. ANOVA showing the mean square values of 7 days NH_4 concentration in floodwater of boro rice field influenced by nitrogen source and application methods

Sources of variation	Degrees of freedom	Mean square values at						
		1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	7Day
Replication	2	1.22	1.62	2.62	3.77	2.76	0.33	0.63
Treatment	6	10.68	13.97	24.17	26.15	20.12	14.18	5.63
Error	12	0.77	1.829	3.76	0.92	0.64	0.20	0.20

Appendix VI. ANOVA showing the mean square values of 7 days NH_4 concentration in soil of boro rice field influenced by nitrogen source and application methods

Sources of variation	Degrees of freedom	Mean square values at						
		1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	7Day
Replication	2	191.74	256.35	165.76	139.88	213.09	29.54	14.02
Treatment	6	656.21*	3852.91	2059.25	1046.24	2020.51	1526.59	1569.28
Error	12	163.42	228.38	297.37	166.34	153.35	77.59	81.04