STUDY ON THE COMPARABLE EFFECT OF UREA SUPER GRANULE (USG) AND NPK BRIQUETTES ON THE GROWTH AND YIELD OF BORO RICE (BRRI dhan28)

MD. MUKIT BIN LIAKAT

DEPARTMENT OF SOIL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

June, 2017

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BY

MD. MUKIT BIN LIAKAT

REGISTRATION NO. 11-04507

A Thesis
Submitted to the Faculty of Agriculture, Dept. of Soil Science
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

SOIL SCIENCE

SEMESTER: JANUARY-JUNE, 2017

Approved by:

____
(Prof. A.T.M. Shamsuddoha)
Supervisor

____
(Prof. Dr. Alok Kumar Paul)
Co-supervisor

____
(*Associate Professor Dr. Saikat Chowdhury*)
Chairman
Department of Soil Science
Sher-e-Bangla Agricultural University

DEPARTMENT OF SOIL SCIENCE
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled ***" COMPARABLE STUDY ON THE EFFECT OF UREA SUPER GRANULE (USG) AND NPK BRIQUETTES ON THE GROWTH AND YIELD OF BORO RICE (BRRI dhan28) "*** *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. MUKIT BIN LIAKAT****, Registration No.* ***11-04507,*** *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:

Dhaka, Bangladesh

(Prof. A.T.M. Shamsuddoha)
Supervisor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedicated to

My Beloved Parents

ACKNOWLEDGEMENTS

All praises goes to Almighty Allah, the Supreme Ruler of the universe who enabled the Author to complete the present piece of work.

I would like to express my heartiest respect, my deep sense of gratitude and sincere, profound appreciation to my supervisor, ***Professor A.T.M. Shamsuddoha ,*** *Department of Agricultural Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

I would like to express my heartiest respect and profound appreciation to my Co-supervisor, ***Professor Dr. Alok Kumer Paul****, Department of Agricultural Soil Science Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.*

I express my sincere respect to the Chairman, ***Associate Professor Dr. Saikat Chowdhury,*** *and all the teachers of Department of Agricultural Soil Science Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

I would like to thank my entire roommates and friends especially Dipu & Plabon to help me in my research work.

Mere diction is not enough to express my profound gratitude and deepest appreciation to my father, mother, sisters, and friends for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate me to this level.

June, 2017 **The Author**

SAU, Dhaka

ABSTRACT

The experiment was conducted during the period from November 2015 to April, 2016 to study the performance of urea super granule (USG) and NPK briquettes on growth and yield of boro rice (BRRI dhan28). The experiment consists of the following treatments: **T_1**: No fertilizer; **T_2**: RFD (Recommended Fertilizer Dose) for Boro rice; **T_3**: 1 granule of NPK of 2.4g weight in between 4 hills + SZn; **T_4**: 2 granule of NPK of 2.4g weight in between 4 hills + SZn; **T_5**: 3 granule of NPK of 2.4g weight in between 4 hills + SZn; **T_6**: 1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn; **T_7:** 2 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn; **T_8**: RFD + 1 Urea super granule of 2.7g weight in between 4 hills. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Application of urea super granule (USG) and NPK briquettes expressed significant influence on growth attributes as well as grain and straw yields of BRRI dha28. The highest grain yield (7.03 t/ha) was obtained in the T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The highest straw yield (7.77 t/ha) was obtained in the T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments. The lowest grain yield (4.09 t/ha) was recorded in T_1 and lowest straw yield (4.78 t/ha) was recorded in T_4. Although maximum number of total grain/panicle (180.87) was obtained in the T_8 but maximum number of filled grain/panicle (157.7) was obtained in the T_6. So, the treatment T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) may be recommended for profitable cultivation of boro rice, BRRI dhan28.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural 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
wt	=	Weight
LSD	=	Least Significant Difference
^0C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Rice (Oryza sativa L.) is a semi-aquatic grass belongs to the family Poaceae. It is the most important food crop of the world and feed more than 4 billion people or 56% of the world's population (IRRI, 2016). Rice is grown in more than a hundred countries with a total harvested area of nearly 157 million hectares, producing more than 740 million tons every year (IRRI, 2016). Asia has the largest growing area with top producing countries including China, India, Thailand, Bangladesh and Vietnam (Xiao *et al*., 2013). It is the staple food for more than two billion people of Asia (Hien *et al*., 2010). This is also the most important source of the food energy for 50% of the Global population (Zhao *et al*., 2011). Rice grain is rich in nutrients and contains a number of vitamins and minerals. Rice provides 21% of global human per capita energy and 15% of per capita protein (IRRI, 2010).

Bangladesh is predominantly an agrarian country. Due to its very fertile land and favorable weather, varieties of crops grow abundantly in this country. Agriculture sector contributes about 17 percent to the country`s Gross Domestic Product (GDP) and employs more than 45 percent of total labour force (Yearbook of Agricultural Statistics, 2016). Rice is the staple food for about 156 million people of Bangladesh (Israt *et al*., 2016). About 28.12 million acres of land is covered in Bangladesh in which 34.7 million M tons of rice is produced while the average yield of rice is around 1.2 tons/acre (Yearbook of Agricultural Statistics, 2016). According to BBS, 2016, Bangladesh is the 4th largest country of the world based on the rice cultivation. In case of Boro rice, it covers the largest area of 1,17,93,512 acres (47,72,576 hectares) acre with a production of 3.96 million tons h^{-1} and the average yield is about 43.02 Maunds/acre during the year of $2015^{-1}6$ (BBS, 2016). In Bangladesh about 82% of the total cropped land is covered by rice (Alam *et al*., 2012). It accounts for 92% of the total food grain production in Bangladesh which provides more than 50% of the agricultural value addition employing about 48% of total rural labour forces , about two-third of total calorie supply and about one-half of the total protein intakes of an average per person in the country. According to the estimation made by BBS, in Bangladesh per capita rice consumption is about 166 kg/year (BBS, 2015).

Food security has been and will remain a major concern in Bangladesh. Rice is also the main food crop of Bangladesh and it covers about 80% of the total cropped area of the country (AIS, 2013). But rice yield, in general, is comparatively lower than that of other south east-asian countries because of imbalanced fertilization, severe insect infestation, drought, salinity etc. The main thing is that in Bangladesh the yield of rice is low compare to the other rice growing countries like Japan, South Korea where the average yield is 6.22 and 7.00 ton per hectare chronologically (Islam *et al*., 2013) and the demand is increasing at an alarming rate in order to feed the increasing population.

Although the soil and climatic conditions of Bangladesh are favorable for rice cultivation throughout the year, the unit area yield is much below to those of other leading rice growing countries of the world. Therefore, emphasis should be given to increase the yield of rice (especially on boro rice). Plant nutrients are essential for cultivation of crops. In rice cultivation system generally, N, P, and K fertilizers are applied in the soil surface as conventional broadcast method. The lion part of those applied fertilizers is getting lost through a number of processes including volatilization, de-nitrification, run-off, leaching and fixation. These result in low crop yield and reduced efficiency of applied nutrients. The nitrogen efficiency especially of urea fertilizer is very low (30-35%) in rice cultivation (IFDC, 2007). Prilled urea (PU) is a very fast releasing nitrogenous fertilizer that usually broadcasted in splits, can cause a considerable loss as ammonia volatilization, de-nitrification, surface run off and leaching etc. (De Datta, 1978), and proposed that to control this loss, deep placement of fertilizer might be a good option to minimize the production cost as well as to increase crop yield.

Many strategies have been developed to increase the efficiency of applied fertilizers through proper timing, rate, deep placement and modified forms of fertilizers. Among them deep placement of fertilizers is one of the most effective methods in reducing loss of nutrients in the flood water and is likely to minimize losses through different processes. Deep placement involves placement of large granules or briquettes of fertilizers at 8-10 cm below the surface. Urea super granule (USG), a physical modification of ordinary urea, is considered a slowly available N fertilizer and found efficient when properly deep placed (Savant and Stangel, 1998). Urea deep placement (UDP) is a proven technology that reduces N losses by up to 50% when compared with the conventional broadcast application of urea (IFDC, 2007). According to Jaiswal and Singh, (2001), deep placement of USG effectively increases N use efficiency (31.7%) compared to conventionally applied prilled urea (PU). Deep placement of USG stops de-nitrification process and minimizes urea concentration in irrigation water. As a result, it reduces nitrogen loss and improves nitrogen use efficiency by 20-25 percent for better grain production (Craswell and De Datta, 1980 and Pillai, 1981). The major N loss reduction results from negligible run-off loss as indicated by lower amounts of N in the flood water and lower ammonia volatilization loss. UDP in flooded soil reduces nitrification (N fertilizer is deep placed in anaerobic soil); hence emission of NO and N_2O gases is reduced. Bhuiyan *et al*. (1998) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU. Further, increases in grain yield, better N use efficiency (kg grain per kg N) and higher apparent N recovery occurred when the hole was closed after USG application.

The use of NPK briquettes, which is a mixture of urea, triple superphosphate and muriate of potash may help in reducing the loss of nutrients in flooded ecosystem. Farmers in Vietnam and Cambodia obtained 25% higher yields with deep placement of NPK briquettes over the broadcasting of fertilizers (IFDC, 2007). In Bangladesh yield of rice was increased by 15-25% while expenditure on commercial fertilizer was decreased by 24-32% when fertilizers briquettes were used as the source of N, P and K (IFDC, 2007). The also observed that NPK briquette can save 33 kg N ha^{-1} compared to recommended PU. Deep placement of fertilizer briquettes also offered environmental and economic benefits (IFPRI, 2004). Bulbule *et al*. (2008) reported that grain yield of rice significantly increased when the crop was fertilized through granules (56-30-30 kg NPK ha^{-1}) as compared to the application of conventional fertilizers (100-50-50 kg NPK ha^{-1}). Therefore, the study will help us to compare the effect of both of those modern fertilizer application tactics for searching the best strategy to get maximum output with minimum inputs.

The aims of the present investigation are the followings:

i. To study the effect of Urea Super Granule and NPK briquettes on the growth and yield of boro rice.

ii. To observe the comparable effect of Urea Super Granule and NPK briquettes on the growth and yield of boro rice.

iii. To find out the suitable dose of Urea Super Granule and NPK briquettes for maximum yield of boro rice.

CHAPTER II

REVIEW OF LITERATURE

A number of research works on the response of rice to urea super granule (USG) and NPK briquettes have been carried out in the rice growing countries of the world including Bangladesh. Since review of literature forms a bridge between the post and present research works related to objectives which helps an investigator to draw a satisfactory conclusion, an effort was made to present some research works related to the present study in this section.

2.1 Effect of N-fertilizer

2.1.1 Plant height

A research was conducted by Abbasi *et al*. (2013) with nitrogen rates at four levels (0, 25, 50 and 75 kg urea ha^{-1}) the result reveal that plant height was significantly affected by urea nitrogen rates and seed inoculation.

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

Aliloo *et al*. (2012) studied the payoffs of foliar spraying of aqueous solutions 2 and 4% urea at two stages (before and after flowering) and 20 kg ha^{-1} urea application on soil. Outcomes showed that the effect of urea treatment on plant height was notable the maximum plant height was obtained by application of 20 kg ha^{-1} urea in soil.

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

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

Ahammed (2008) investigated 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) got that effect of depth of placement of USG significantly influenced all growth indications and the yield attributes except plant height.

Salem (2006) stated 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 maximum 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.

Oad and Buriro (2005) conducted a field research to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of rice. AEM 96 in Tandojam, Pakistan. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.25.

Rahman (2003) observed that plant height did not affected by the different level of USG in rice. He carried out an experiment with two levels of urea super granules (USG) in rice field as 50 and 75 kg N ha^{-1} in kharif season. He found that the highest plant height (83cm) was obtained with 75 kg N ha^{-1} as USG. But highest tiller number (14.32), panicle length (20.24 cm), grains $panicle^{-1}$ (91.44), 1000 seed weight (22.58 g), grain yield (3.12 t ha^{-1}) and straw yield (5.34 t ha^{-1})

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).

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.

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.

Duhan and Singh (2002) conducted a field trail and reported that the rice yield and uptake of nutrients enhanced significantly with increasing N levels.

Angayarkanni and Ravichandran (2001) conducted a field research in Tamil Nadu, India from July to October 1997 to infer the best split application of 150 kg N ha^{-1} for rice cv. IR 20. They found that applying 16.66% of the recommended N as basal, followed by 33.33% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT recorded the utmost grain (6189 kg ha^{-1}) and straw (8649 kg ha^{-1}) yields, reply ratio (23.40) and agronomic efficiency (41.26).

Chopra and Chopra (2000) indicated that application of either 80 or 120 kg N ha^{-1} uplifted the entire yield attributes of rice comparing to the control.

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.

Singh *et al*. (2000) reported that each increment dose of N significantly enhanched grain and straw yields of rice over its previous dose. Consequently, the crop fertilized with 100 kg N ha^{-1} gave the highest grain yield (2647 kg ha^{-1}).

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.

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.

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.

Rekhi *et al*. (1989) conducted an experiment on a loamy sand soil with rice cv. PR 106 providing 0, 37.5, 75.0 or 112.5 kg N ha^{-1} as prilled urea (PU) or USG. PU was applied in three equal splits at transplanting, tillering, and panicle initiation and USG was placed 8^{-1}0 cm deep in alternate rows, equidistant from 4 hills. They found that PU produced the longest plant, higher number of panicles and higher amount of nitrogen uptake.

Singh and Singh (1986) reported that the plant height increased significantly with the increase in the levels of nitrogen from 27 to 87 kg N ha^{-1}. Deep placement of USG resulted in the highest plant height than pilled urea.

The varieties differing in plant type markedly differ in their response to added nitrogen levels (Evant *et al*, 1960; Tanaka *et al*, 1964). Nitrogen fertilization also influenced the plant height (Talukdar, 1973; Hoque *et al*., 1977; BRRI, 1989).

2.1.2 Number of effective tillers hill^{-1}

Masum *et al*. (2010) reported that placement of N fertilizer in the form of USG @ 58 kg N ha^{-1} produced the highest number of effective tillers hill^{-1}, filled grains panicle^{-1} which ultimately gave the higher grain yield than split application of urea.

Azam (2009) conveyed an experiment with 3 varieties and seen, in general, the number of total tillers hill^{-1} was increased as the USG level increased but maximum no. of total tillers hill^{-1} was produced when 55 kg N ha^{-1}applied as USG.

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

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

Alam (2002) seen 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.

Krishnan and Nayak (2000) got that increasing levels of N application resulted in more secondary tillers which contributed little grain resulting in low harvest index.

Ahsan (1996) narrated that tillering is strongly correlated with nitrogen content of the plant. The increment level of nitrogen increase the number of tiller hill^{-1}. Results expressed that the maximum number of tiller hill^{-1} (31) was obtained at 150 kg N ha^{-1} and reduced with the lower level of nitrogen.

Mirzeo and Reddy (1989) operated with different modified urea materials and levels of N (30, 60 and 90 kg N ha^{-1}). They reported that root zone placement of USG produced the maximum number of tillers at 30 or 60 days after transplanting.

Tillering of rice plant is strongly affected by nitrogen supply (IRRI, 1968; BRRI, 1989) and adequate nitrogen is essential during tillering stage to confirm sufficient number of panicle bearing tillers (Hall and Tacket, 1962) .

2.1.3 Number of Grains panicle^{-1}

Zohra *et al*. (2012) investigated that the number of grains panicle^{-1}was varied significantly due to different level of USG.

Rajarathinam and Balasubramaniyan (1999) reports that there was no contextual change in grains panicle^{-1} due to higher dose of N above 150 kg ha^{-}

^{1}. They also observed an appreciable reduction in grains panicle^{-1} at 250 kg N ha^{-1}

Idris and Matin (1990) stated that the length of panicle of rice was highly related with the application of increased level of nitrogen. They also noted that panicle formation and elongation was directly concerned with the contribution of nitrogen.

Jee and Mahapatra (1989) noticed that number of panicles m-2 were significantly higher with 90 kg N ha^{-1} as deep placed USG than split application of urea.

Singh and Kumar (1983) reported that grain yield increased consistently with increasing N application up to 87 kg ha^{-1} USG produced the higher grain yield than ordinary urea applied in three equal split dressings and other N sources.

Lal *et al*. (1983) studied the effects of rooted placement of USG or PU on yields of cv. Jaya and Govind published that with random transplanting, deep placement of USG enhanced yield of cv. Jaya and Govind by 0.4 and 1.1 t ha^{-1}

Yosida and Parao (1976) stated that in rice at higher nitrogen level the number of grain become reduced due to lodging.

2.1.4 Weight of 1000-grain (g)

Azam *et al*. (2009) investigated 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 reported that source and dose of nitrogen did not show significant effect on 1000-grain weight. The maximum 1000-grain weight (24.70 g) was obtained with USG applied at 55 kg N ha^{-1} and minimum (24.09 g) 1000-grain weight was observed at 110 kg N ha^{-1}as PU.

Chopra and Chopra (2004) expressed that N had significant effects on yield attributes such as plant height, panicle plant^{-1} and 1000-grain weight. Accretive effect of yield attributing and nutrient characters produced 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 guided by Maiti *et al*. (2003) during the boro season with the nitrogen fertilizer applied during transplanting, at the tillering and panicle initiation stages. They got increased number of higher number of panicles, number of filled grains panicle^{-1},1000-grain weight and grain yield.

Chopra and Sinha (2003) guided an experiment with the treatments included of 4 N levels (0, 60, 120 and 180 kg N ha^{-1}) and results expressed 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 evolved in significant increase and seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1}.

Alam (2002) reported that 1000-grain weight was not influenced by level of USG.

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

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

Ali *et al*. (1993) reported that weight of 1000 grains was higher when 100 kg nitrogen ha^{-1}was applied in three equal splits at basal 30 days and 60 days after transplanting.

Rahman *et al*. (1985) stated that there was a little relationship between nitrogen and weight of 1000 grains of rice.

2.1.5 Grain and straw yield (t ha^{-1})

Choudhury *et al*. (2013) conducted three different experiments in three locations in Bangladesh (Jessore, Patuakhali and Mymensingh) to determine the performance of rooted placement of NPK briquette compared to broadcast incorporation of N, P and K on vegetables like cucumber, taro and bitter gourd. The results expressed that deep placement of NPK briquette gave higher crop yield and higher gross margin over broadcast incorporation N, P and K. In addition to that the amount of NPK nutrient uptake and recovery by all the three crops was also higher in NPK briquette treatment compared to broadcast treatment of prilled urea, triple superphosphate and muriate of potash.

Shah *et al*. (2013) conducted twelve experiments at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, BRRI regional station Sagordi, Barisal and farmers' field in 2012 to determine the NPK briquette efficacy in rice production. Experimental results expressed that deep placement of NPK briquette (2 x 2.4g) increased rice yield about 10 percent and it saved 37 percent N, 30 percent P and 44 percent K than BRRI fertilizer recommended rate in boro season. Similarly, NPK briquette (1 x 3.4g) produced 28 percent and 18 percent more rice yield than BRRI fertilizer recommended rate for T. aus and T. aman, respectively. Thus, use of NPK briquette over NPK broadcast and incorporation was very much efficient for rice cultivation.

Zohra *et al*. (2012) conducted an experiment with different level of USG on 3 different varieties of T. aman rice. Among the 6 doses of USG, maximum grain yield was produced when the crop was fertilized with 2 pellet of USG/4 hills and minimum grain yield was recorded in the control treatment.

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

Islam *et al*. (2011) conducted 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.

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

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

BRRI (2009) conducted an experiment on study of N release pattern from USG and prilled urea under field condition and its effect on grain yield and N nutrition of rice with three doses of N namely 50, 100 and 150 kg N ha^{-1}from two types of urea e.g. prilled (PU) and urea super granules (USG) were tested as treatment. Result showed that the highest grain yield was recorded when N applied @ 100 kg N ha^{-1} both from USG and PU and the highest straw yield was obtained in PU @ 150 kg N ha^{-1}.

Hasanuzzaman *et al*. (2009) conducted an experiment to study the economic and effective method of urea application in rice crop. They noted that urea supergranules produced longest panicle (22.3 cm).

Kabir *et al*. (2009) conducted an experiment to find out the effect of urea super granules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield contributes of transplant aman rice. They observed that the highest grain yield (5.17 t ha^{-1}), straw yield (6.13 t ha^{-1}) and harvest index (46.78%) were found from full dose of USG.

Bulbule *et al*. (2008) conducted an experiment to study the effects of NPK briquettes on yield and nutrient content of rice. The results exposed that grain yield of rice significantly increased when the crop was fertilized through briquettes (56-30-30 kg NPK ha^{-1}) as compared to the application of conventional fertilizers (100-50-50 kg NPK ha^{-1}).

In a field experiment on agronomy field laboratory, BAU, Hussain (2008), assessed 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 declined.

Masum *et al*. (2008) conducted an experiment to study the effect of four levels of seedling hill^{-1} viz; 1, 2, 3 and 4 and two forms of nitrogen – prilled urea (PU) and urea supergranules (USG) on yield and yield components of modern (BRRI dhan44) and traditional (Nizershail) transplant aman rice. They reported that leaf area index significantly higher in USG receiving plant than prilled urea.

Singh *et al*. (2008) reported that the deep-point placement of N, P and K briquettes significantly increased grain and straw yields, total N, P and K uptake, also N and P use efficiencies compared to broadcast incorporation of N, P and K in rice.

Kapoor *et al*. (2008) filed that deep placed N–P briquettes gave significantly higher grain yield, straw biomass, total P and K uptake, apparent P recovery, and agronomic N and P use efficiencies, when plant spacing was reduced from 20 x 20 cm to 20 X 10 cm. Closer plant spacing led to better utilization of P and K and provided opportunities for deep placement of N–P or N–P–K briquettes in soils with low available P. Assembling site specific characteristics viz., high soil pH, low percolation rate, high rainfall and surface runoffs with plant spacing and N–P–K briquettes prepared based on site specific nutrient requirements offered potential for higher yields, improved fertilizer use efficiency, balanced fertilization, and reduced nutrient losses.

Peterson (2007) reported that placement of compound NPK fertilizer increased the grain yield and the quality parameters like grain size and grade when weeds are managed mechanically by harrowing in barley. The effect of fertilizer placement on grain yield and quality decreased in the order NPK> NP> N> P.

Hasan (2007) showed the effect of level of USG significantly impact on the yield attributes except 1000 grain weight. In his experiment, the maximum 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

Xie *et al*. (2007) in his experiment got that the level of nitrogen application depends on the variety for obtaining the highest grain yield.

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

Asha *et al*. (2006) reported that deep placement using nutriseed holder resulted in the grain yield direct seeded rice increase to the tune of 81.8 per cent over surface broadcast.

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

Mashkar and Thorat (2005) carried out a field experiment during the 1994 kharif season in Konkan, Maharashtra, India, to determine 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).

Miah *et al*. (2004) found that the values of the parameters measured were higher with application of urea super granules compared to application of urea.

Singh *et al*. (2000) reported that each increment dose of N significantly increased grain and straw yields of rice over its preceding dose. Therefore, the crop fertilized with 100 kg N ha^{-1} gave the maximum grain yield (2647 kg ha^{-1}).

2.1.6 Biological yield (t ha^{-1})

Gaudin (2012) conducted an experiment on the kinetics of ammonia disappearance from deep-placed urea super granules (USG) in transplanted rice: the effects of rooted placement USG application and PU fertilizer. He observed 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.

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

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

2.1.7 Harvest index (%)

Sarker *et al*. (2001) reported 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 experienced that application of nitrogen increased grain and straw yields significantly but harvest index was not increased significantly.

Dwivedi (1997) observed 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^{-1}.

2.2 Effect of urea super granules (USG) on crops

Xiang *et al*. (2013) conducted an experiment in International Rice Research Institute (IRRI) farm to examine the effect of different methods of nitrogen application on plant growth of aerobic rice grown in continuous aerobic rice system. The field micro-plot experiment showed that urea and urea super granules (USG) deep placement increased grain yield of aerobic rice by 1.66 t ha^{-1} in continuous aerobic rice cultivation. They also suggested that there is a possibility of improving aerobic rice yield in the continuous aerobic rice system by using right N source or changing conventional method of nitrogen application to deep placement.

Hasanuzzaman *et al*. (2013) conducted an experiment at Sher-e-Bangla Agricultural University, Dhaka during the period of November 2010 to May 2011 to study the influence of prilled urea and urea super granules on the growth and yield of hybrid rice Heera1. The treatments consisted of six prilled urea levels viz. 0, 80, 120, 160, 200 kg N ha^{-1} and urea super granule @ 75 kg N ha^{-1}). The effect of USG showed significant variation in respect of growth, yield contributing characters and yield. At harvest, the highest number of effective tillers $hill^{-1}$ (13.63), filled grains $panicle^{-1}$ (154.67), 1000- grain weight (29.35 g), grain yield (9.42 t ha^{-1}) and straw yield (13.33 t ha^{-1}) were obtained from the application of USG showing 10% more grain yield than PU.

Sarker *et al*. (2012) conducted an experiment in Sylhet under AEZ-20 (Eastern Surma-Kushiyara Floodplain) during 2007-08 and 2008-09 to find out the effect of Urea super granule (USG) on cabbage. Results revealed that yield of cabbage increased significantly due to application of USG over PU. The highest head yield of cabbage 92.04 and 91.36 t ha^{-1} were obtained from the USG (recommended dose) in 2007-08 and 2008-09, respectively which was statistically similar with USG 10% less than recommended dose (84.78 t ha^{-1}) instead of traditional PU.

Gaudin (2012) carried out an experiment on the kinetics of ammonia disappearance from deep-placed urea super granules (USG) and broadcast application of PU in transplanted rice. 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.

Das *et al*. (2012) conducted an experiment at Mymensingh during December 2008 to May 2009 to evaluate the influence of spacing of transplanting and rate of urea super granules on the yield of boro rice. The experiment consisted of two spacing of transplanting and three rates of urea super granules. The higher grain yield (4.46 t ha^{-1}) was obtained from 20 cm × 20 cm spacing. They also found that rates of urea super granules significantly influenced all the yield contributing characters except weight of 1000-grain and length of panicle. The maximum effective tillers $hill^{-1}$ (14.60), grains $panicle^{-1}$ (109.1), grain yield (5.80t ha^{-1}) and harvest index (44.90%) were obtained from 2.7g USG (68 kg N ha^{-1}).

Azam *et al*. (2012) conducted a field experiment at the agronomy field of Shere- Bangla Agricultural University, Dhaka to find out the influence of variety and different urea fertilizer application method on growth and yield of boro rice. The experiment was carried out in split-plot design with three replications having three varieties. Result showed that variety and urea fertilizer application method had significant effect on plant height, tillers $hill^{-1}$, dry weight $hill^{-1}$, grains $panicle^{-1}$, leaf area index, 1000-grain weight, grain yield, straw yield and harvest index. Urea super granule treated plots showed better performance than that of prilled urea.

Choudhury *et al*. (2009) conducted a field experiment at Bangladesh Rice Research Institute to evaluate the effect of urea super granule (USG) deep point placement compared to conventional prilled urea (PU) broadcasting with respect to yield and nitrogen nutrition of wetland rice (Variety BR11). The result showed that USG treated plots gave higher grain and straw yields compared to PU treated plots within same dose of added N. In addition to that total N uptake by BR11, agronomic efficiency and apparent recovery of added N were also higher with USG compared to PU within the same N dose.

Tang *et al*. (2007) performed an experiment to explore the mechanism of single basal application of controlled-release fertilizers for increasing yield of rice (*Oryza sativa* L.). Results showed that at 30 days after fertilization, single basal application of controlled-release fertilizers coated with vegetal-substance (CRF1) and polymer materials (CRF3) increased soil available N, superior development of root systems, better nutrient absorption capacity, slower senescence and enhancement of lodging resistance at late stages in comparison to split fertilization of rice-specific fertilizer (RSF1).

Hasan (2007) conducted an experiment during the aman season of 2006 and recorded the increased number of tillers per hill with increased nitrogen level as USG. He showed that different levels of USG did not have any significant effect on 1000- grain weight of three aman rice cultivars.

Humphreys *et al*. (2006) reported that recovery of nitrogen from point placement of urea of super granule was 49% higher than prilled urea. The increase in plant nitrogen recovery consequently increases plant height, number of leaf, tillering and a yield or agronomic efficiency of rice plant.

Deivanai (2005) experimented with Nutriseed holder which contained seed on top cavity, manure in the middle tube and fertilizer at bottom cavity, which gave 42-58 per cent increase in ADT 36 rice yield grown in soil column, when compared to surface broadcast method, under submerged water regime.

Alam *et al*. (2000) carried out a socio economic study in two rice production environment (Gazipur and Tangail) to assess the comparative advantages of using urea super granule (USG) over prilled urea (PU) in modern rice production and to examine the differences in producers technical efficiency between USG urea and non-user in crop management. Results revealed that comparatively low amount (36%) of urea was needed in modern boro rice production using USG instead of PU though 15% more labour was needed while weeding cost was a bit lower in USG using plots. Results also indicated additional yield of 0.87 t ha^{-1} by using USG and this yield gain additional benefit of TK. 11,506 ha^{-1}.

Department of Agricultural Extension (DAE) conducted 432 demonstrations of the effect of USG on boro rice in 72 thanas of 31 districts. It was reported that USG plots, on an average, produced higher yields than the PU plots while applying 30 to 40% less urea in the form of USG (Islam and Black, 1998).

2.3 Effect of NPK briquettes

Shah *et al*. (2013) carried out twelve experiments at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, BRRI regional station Sagordi, Barisal and farmers' field in 2012 to evaluate the NPK briquette efficacy in rice production. Experimental results revealed that deep placement of NPK briquette (2 x 2.4g) increased rice yield about 10 percent and it saved 37 percent N, 30 percent P and 44 percent K than BRRI fertilizer recommended rate in boro season. Similarly, NPK briquette (1 x 3.4g) produced 28 percent and 18 percent more rice yield than BRRI fertilizer recommended rate for T. aus and T. aman, respectively. Thus, use of NPK briquette over NPK broadcast and incorporation was very much efficient for rice cultivation.

Choudhury *et al*. (2013) conducted three different experiments in three locations in Bangladesh (Jessore, Patuakhali and Mymensingh) to determine the performance of rooted placement of NPK briquette compared to broadcast incorporation of N, P and K on vegetables like cucumber, taro and bitter gourd. The results expressed that deep placement of NPK briquette gave higher crop yield and higher gross margin over broadcast incorporation N, P and K. In addition to that the amount of NPK nutrient uptake and recovery by all the three crops was also higher in NPK briquette treatment compared to broadcast treatment of prilled urea, triple superphosphate and muriate of potash.

Islam *et al*. (2011) conducted 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.

Kapoor *et al*. (2008) filed that deep placed N–P briquettes gave significantly higher grain yield, straw biomass, total P and K uptake, apparent P recovery, and agronomic N and P use efficiencies, when plant spacing was reduced from 20 x 20 cm to 20 X 10 cm. Closer plant spacing led to better utilization of P and K and provided opportunities for deep placement of N–P or N–P–K briquettes in soils with low available P. Assembling site specific characteristics viz., high soil pH, low percolation rate, high rainfall and surface runoffs with plant spacing and N–P–K briquettes prepared based on site specific nutrient requirements offered potential for higher yields, improved fertilizer use efficiency, balanced fertilization, and reduced nutrient losses.

Singh *et al*. (2008) reported that the deep-point placement of N, P and K briquettes significantly increased grain and straw yields, total N, P and K uptake, also N and P use efficiencies compared to broadcast incorporation of N, P and K in rice.

Bulbule *et al*. (2008) carried out an experiment to study the effects of NPK briquettes on yield and nutrient content of rice. The results showed that grain yield of rice significantly increased when the crop was fertilized through briquettes (56-30-30 kg NPK ha^{-1}) as compared to the application of conventional fertilizers (100-50-50 kg NPK ha^{-1}).

Peterson (2007) found that placement of compound NPK fertilizer increased the grain yield and the quality parameters like grain size and grade when weeds are controlled mechanically by harrowing in barley. The effect of fertilizer placement on grain yield and quality decreased in the order NPK>NP> N> P.

CHAPTER III

MATERIALS AND METHODS

This chapter highlights the experimental work. The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) Farm, Sher-e-Bangla Nagar, Dhaka. The aim of the study was to evaluate the effects of comparable study on the effect of urea super granule (USG) and NPK briquettes on the growth and yield of boro rice. A brief description about the experimental period, experimental site, climate, soil, land preparation, layout of the experimental design, treatments, seedling transplanting, intercultural operations, harvesting, data recording, collection and preparation of soil and plant samples and the methods for the chemical and statistical analysis are presented in this section.

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 November 2016 to May 2017.

3.1 Description of the experimental site and soil:

3.1.1 Geographical location

The experimental site is geographically situated at 23°77' N latitude and 90°33' E longitude at an altitude of 8.4 meter above sea level. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988). The morphological, physical and chemical characteristics of the soil are shown in the Tables 1 and 2. Experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.1.2 Climate

The climate of the experimental site is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the kharif season (March-September) and during Rabi season (October-March) scanty rainfall associated with moderately low temperature is observed. The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental area during the cropping season November 2016 to May 2017 have been presented in Appendix II .

Table 1. Morphological characteristics of the experimental field.

Morphology	Characteristics
Location	SAU Farm. Dhaka
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

Source: (FAO and UNDP, 1988)

Table 2. Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions: % Sand (0.2-0.02 mm) % Silt (0.02-0.002 mm) % Clay (<0.002 mm)	 22.53 56.72 20.75
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.8
Organic C (%)	0.686
Organic Matter (%)	1.187
Total N (%)	0.08
Exchangeable K(cmol kg^{-1})	0.12
Available P (mg kg^{-1})	19.85
Available S (mg kg^{-1})	14.40

This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur 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.

3.1.3 Soil

The soil of the experimental field belongs to the general soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.6-6.2. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from the experimental field. The soil analyses were done at Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207. The physicochemical properties of the soil are presented in Table 2.

3.2 Experimental Details

3.2.1 Planting Material

BRRI dhan28 is a high yielding variety of rice was used in this experiment as the test crop. The variety was developed by Bangladesh Rice Research Institute in 1994. Life cycle of this variety is 140 days. Height of mature plants is 90 cm and plants do not lodge. Insect and pest attack are comparatively less in BRRI dhan28.

3.2.2 Treatments

There were altogether eight different treatments which include:

- T_1: No fertilizer
- T_2: RFD (Recommended Fertilizer Dose) for boro rice.
- T_3: 1 granule of NPK of 2.4g weight in between 4 hills + SZn.
- T_4: 2 granule of NPK of 2.4g weight in between 4 hills + SZn.
- T_5: 3 granule of NPK of 2.4g weight in between 4 hills + SZn.
- T_6: 1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn.
- T_7: 2 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn.
- T_8: RFD + 1 Urea Super Granule of 2.7g weight in between 4 hills.

3.2.3 Experimental design

The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into 3 blocks representing the replications to reduce the heterogenic effects of soil. There were 8 different treatments combinations. Each block was subdivided into 8 plots and the treatments were randomly distributed to the unit plot in each block. Thus the total number of unit plot was 24. The size of each plot was 4 m x 2.5 m and plots were separated from each other by ails (75 cm). There was 1 m drain between the blocks that separated the blocks from each other. For better understanding the layout of the experiment has been presented in Appendix III.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI, Gazipur just 15 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. These were then taken out of water and kept in a gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing within 72 hours.

3.3.2 Raising of seedlings

The nursery bed was 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. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The land was first opened on 15 December 2016 by a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling.

3.3.4 Application of fertilizers

The fertilizers were applied as per treatment. All the treatments except T_1, T_3, T_4 and T_5 received 36 kg P ha^{-1} and 72 kg K ha^{-1} from TSP and MoP, respectively. In T_3, T_4 and T_5 treatments, P and K were supplied from NPK briquettes. Sulphur 36 kg ha^{-1} and zinc 6.4 kg ha^{-1} were applied to all plots (except T_1) as basal dose from gypsum and zinc oxide, respectively. PU was applied in three equal splits. The first dose of PU was applied 10 days after transplanting (DAT), the second dose was added as top dressing 35 DAT (active tillering stage) and the third dose was top-dressed 55 DAT (panicle initiation stage. USG and NPK briquettes were applied at 10 DAT and urea super granule and NPK briquettes were placed at 8-10 cm depth between four hills at alternate rows. Before application of N fertilizers, the water in the rice plots was drained out.

3.3.5 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.3.6 Transplanting of seedling

Thirty days old seedlings of BRRI dhan28 were carefully uprooted from the seedling nursery and transplanted on 29 December, 2015. Three seedlings $hill^{-1}$ were used following a spacing of 20 cm × 20 cm. After one week of transplanting, all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.3.7 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.3.8 Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

3.3.9 Weeding

During plant growth period two hand weeding were done, first weeding was done at 26 DAT (Days after transplanting) followed by second weeding at 43 DAT.

3.3.10 Application of irrigation water

Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

3.3.11 Method of water application

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed to measure depth of irrigation water.

3.3.12 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of Diazinone 60 EC on 20 February and 18 March, 2016. Crop was protected from birds by net during the grain filling period.

3.3.13 General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper was observed during tillering stage. But any bacterial and fungal disease was not observed. The flowering was not uniform. Lodging did not occur in during the heading stage due to heavy rainfall with gusty winds.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 20 May, 2017 when 80-90% of the grains were turned into straw colored. The harvested crop was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of rice grain. Fresh weight of rice grain and straw were recorded plot wise from 1 m^2 area. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 14%. Yields of rice grain and straw m^{-2} were recorded and converted to t ha^{-1}.

3.5 Recording of Data

A. Crop growth characters

1. Plant height (cm)

2. Tillers $hill^{-1}$(no.)

3. Effective tillers $hill^{-1}$ (no.)

4. Non-effective tillers $hill^{-1}$ (no.)

5. Length of flag leaf (cm)

B. Yield contributing characters

5. Panicle length (cm)

6. Filled grains $panicle^{-1}$

7. Unfilled grains $panicle^{-1}$(no.)

8. Weight of 1000-grains (g)

C. Yield

9. Grain yield (t ha^{-1})

10. Straw yield (t ha^{-1})

11. Biological yield (t ha^{-1})

12. Harvest index (%)

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of harvesting stage. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.5.2 Effective tillers $hill^{-1}$

The total number of effective tillers $hill^{-1}$ was counted as the number of panicle bearing tiller during harvest. Data on effective tillers $hill^{-1}$ were counted from 10 selected hills and average value was recorded.

3.5.3 Non-effective tillers $hill^{-1}$

The total number of non-effective tillers $hill^{-1}$ was counted as the number of non-panicle bearing tillers during harvesting. Data on non- effective tillers $hill^{-1}$ were counted from 10 selected hills and average value was recorded.

3.5.4 Total tillers $hill^{-1}$

Tillers $hill^{-1}$ were counted and averaged as number $hill^{-1}$. Only those tillers having three or more leaves were considered for counting.

3.5.5 Length of flag leaf (cm)

The length of flag leaf was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.5.6 Filled grains $panicle^{-1}$

The total numbers of filled grain was collected randomly from selected 10 plants of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.7 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 10 plants of a plot on the basis of no grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.8 Weight of 1000 grain

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in grams and recorded.

3.5.9 Grain yield t ha^{-1}

Grains obtained from each unit plot were sun-dried and weighed carefully. The grain dry weight of each plot was recorded for the final grain yield plot^{-1} and finally converted to t ha^{-1}.

3.5.10 Straw weight (kg)

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of the respective unit plot yield was converted to ton per ha.

3.5.11 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.12 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

3.6 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.7 Analyses of soil samples

Soil samples were analyzed for both physical and chemical properties such as texture, pH, organic carbon, total nitrogen, available P and exchangeable K.

The soil samples were analyzed following standard methods as follows:

3.7.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values of% sand, % silt and % clay to the Marshall's triangular co-ordinate following the USDA system.

3.7.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil: water ratio of 1: 2.5 as described by Jackson (1962).

3.7.3 Organic carbon

Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

3.8 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of BRRI dhan28. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test and Microsoft Office Excel 2007. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez *et. al.*, 1984).

CHAPTER IV

RESULT AND DISCUSSION

This chapter presents the effects of urea super granule (USG) and NPK briquettes on growth and yield of boro rice (BRRI dhan28). Treatments effect of urea super granule (USG) and NPK briquettes have been presented in various tables and figures and discussed under the following subsections.

4.1 Plant height (cm)

Plant height of BRRI dhan28 responded significantly in all of the treatments used in this experiment due to the application of urea super granule (USG) and NPK briquettes. Effect of nutrient source showed a significant variation on plant height (Figure 1). At harvest, the tallest plant (100.4 cm) was recorded from T_7 treatment (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn) which was statistically similar with T8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) & T6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn), and the shortest plant (78.32 cm) was recorded from the T_1 treatment (control).

The results were similar with the findings of Meena *et al.* (2003), Sahrawat *et al.* (1999) and Thakur *et al.* (1993) who observed higher plant height with the higher doses of nutrient.

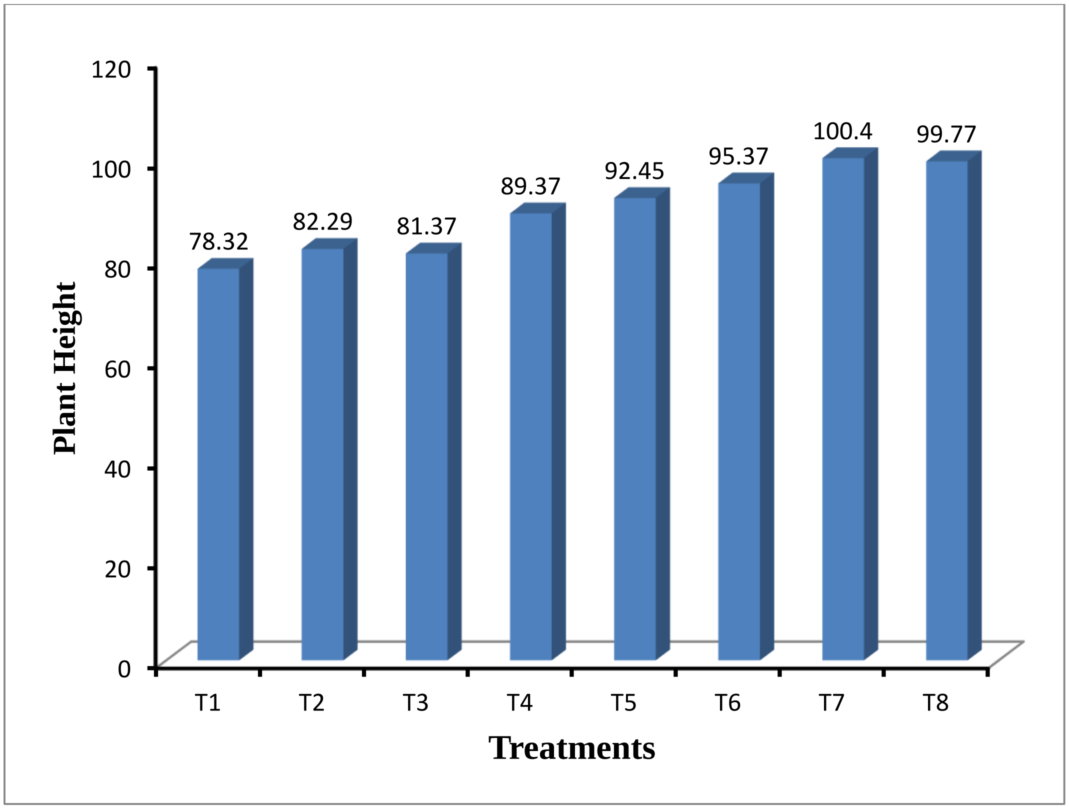

Figure 1: Effects of urea super granule (USG) and NPK briquettes on plant height of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn .

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

Table: 3. Effects of urea super granule(USG) and NPK briquettes on plant height (cm), length of flag leaf(cm), no. of effective tiller/hill and panicle length of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

Treatments	Plant Height (cm)	Length of Flag Leaf(cm)	No. of effective tiller/Hill	Panicle Length
T_1	78.32 c	26.47 d	9.00 e	21.70 bc
T_2	82.29 c	28.33 cd	15.00 bc	24.29 a
T_3	81.37 c	23.33 e	16.00 ab	20.50 c
T_4	89.37 b	34.43 a	17.00 a	23.43 ab
T_5	92.45 b	31.51 ab	14.00 cd	22.36 abc
T_6	95.37 ab	29.32 bcd	13.00 d	23.47 ab
T_7	100.4 a	33.47 a	17.33 a	23.29 ab
T_8	99.77 a	30.43 bc	17.33 a	24.33 a
LSD(.05)	5.766	2.886	1.558	1.829
CV	3.66	26.47	6.02	4.56

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.2 Length of Flag Leaf

The effect of different treatments on Length of Flag Leaf was statistically significant (Figure 2). The maximum length of Flag Leaf (34.43) was obtained in the T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment except T_7 treatment (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn). The second highest length of flag leaf (33.47) was obtained in the T_7 (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.) treatment which was statistically similar with T_4 treatment. The minimum length of flag leaf (26.47) was obtained in the T_1 control (no fertilizer) treatment. It was observed that length of flag leaf increased with increasing doses of nutrient.

BRRI (2006), Ahsan *et al.* (1996), Kumar *et al.* (1995) and ldris *et al.* (1990) reported similar result that supports the present findings.

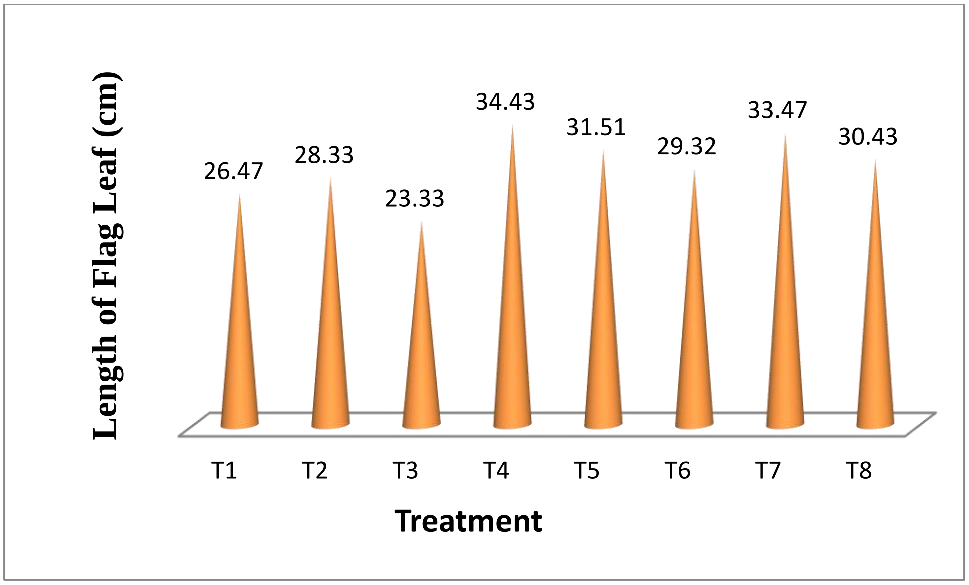

Figure 2: Effects of urea super granule (USG) and NPK briquettes on length of flag leaf (cm) of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.3 Effective Tillers/Hill

The use of urea super granule (USG) and NPK briquettes significantly influenced the number of effective tillers hill^{-1} of BRRI dhan28. Figure 3 shows the effects of different treatments on effective tillers/hill. The highest number of effective tillers/hill (17.33) was obtained in the T_7 (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment and T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) which was statistically similar with T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills + SZn) and T_3 (1 briquette of NPK of 2.4g weight in between 4 hills + SZn) treatment. The second highest effective tillers/hill (17) was obtained in the T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills + SZn) treatment. The minimum number of effective tillers/hill (9) was obtained in the T_1 control (no fertilizer) treatment. It was observed that the number of effective tillers/hill increased with increasing levels of nutrient.

Hari *et al.* (2000), Thakur *et al.* (1991a) and Tanaka *et al.* (1964) also found similar result that increasing levels of nutrient increased the number of effective tillers.

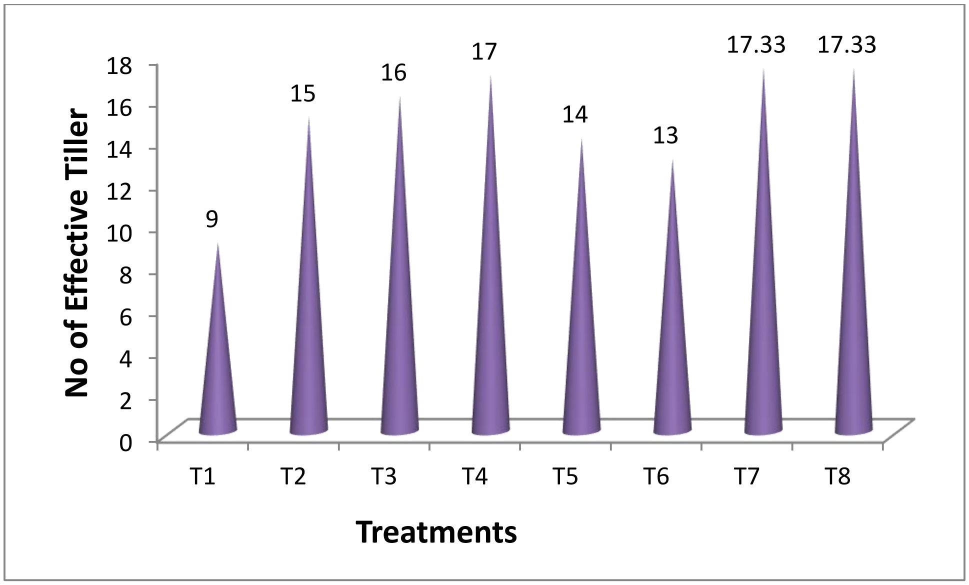

Figure 3: Effects of urea super granule (USG) and NPK briquettes on effective tillers/hill of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.4 Panicle length (cm)

The length of panicle was significantly influenced by the application of urea super granule (USG) and NPK briquettes (Figure 4) and showed a significant variation. At harvest, the highest panicle length (24.33 cm) was recorded from T_8 treatment (RFD + 1 Urea super granule of 2.7g weight in between 4 hills). which was statistically similar with T_2 (RFD for boro rice), T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills + SZn), T_5 (3 briquettes of NPK of 2.4g weight in between 4 hills + SZn), T_6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn) and T_7 (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment. The shortest panicle length (20.50 cm) was recorded from the T_3 treatment (1 briquette of NPK of 2.4g weight in between 4 hills) which was statistically similar with T_1 treatment (control).

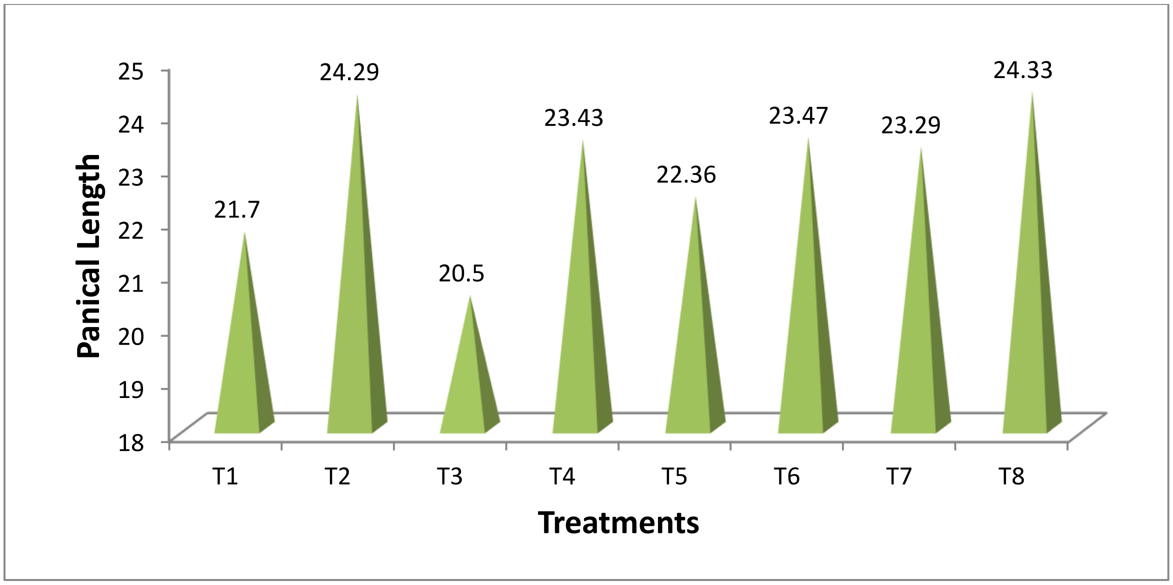

Figure 4: Effects of urea super granule (USG) and NPK briquettes on panicle length of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

Table: 4. Effects of urea super granule(USG) and NPK briquettes on no. of total grain panicle^{-1}, no. of filled grain/panicle and no. of unfilled grain panicle^{-1} of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

Treatments	No. of Total Grain/Panicle	No. of Filled Grain/Panicle	No. of Unfilled Grain/Panicle
T_1	94.4 f	80.67 d	13.73 e
T_2	124.37 e	109 c	15.37 de
T_3	139.13 d	127.7 b	11.43 e
T_4	157.13 c	137.7 b	19.43 cd
T_5	160.18 c	138.3 b	21.88 c
T_6	171.1 b	154.7 a	16.40 de
T_7	167.73 c	133.3 b	34.40 b
T_8	180.87 a	139.3 b	41.57 a
LSD(.05)	2.637	14.11	5.03
CV	5.28	6.32	13.73

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.5.1 Number of total grains/panicle

Figure 5 shows the effects of urea super granule (USG) and NPK briquettes on grains/panicle of BRRI dhan28. It was found that total number of grains/panicle were statistically significant. The maximum number of total grains/panicle (180.87) was obtained in the T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills. treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The second highest total grains/panicle (171.1) was obtained in the T_6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment. The minimum number of total number of grains/panicle (94.40) was obtained in the T_1 treatment (control). It was observed that the number of total grains/panicle increased with increasing levels of nutrient.

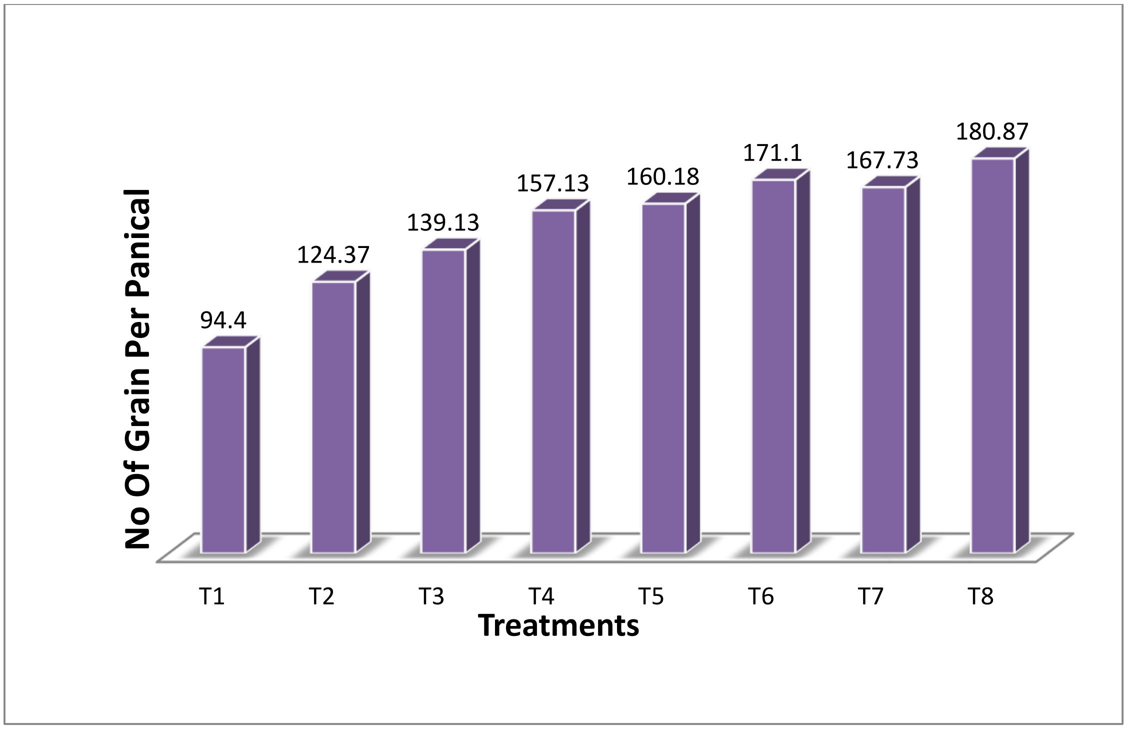

Figure 5: Effects of urea super granule (USG) and NPK briquettes on Total grains/panicle of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.5.2 Number of filled grains/panicle

Figure 6 reports the effects of urea super granule (USG) and NPK briquettes on filled grains/panicle of BRRI dhan28. The number of filled grains/panicle varied from 80.67 to 154.7 with the highest value in T_6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The minimum number of filled grains/panicle (80.67) was obtained in the T_1 control (no nutrient fertilizer) treatment.

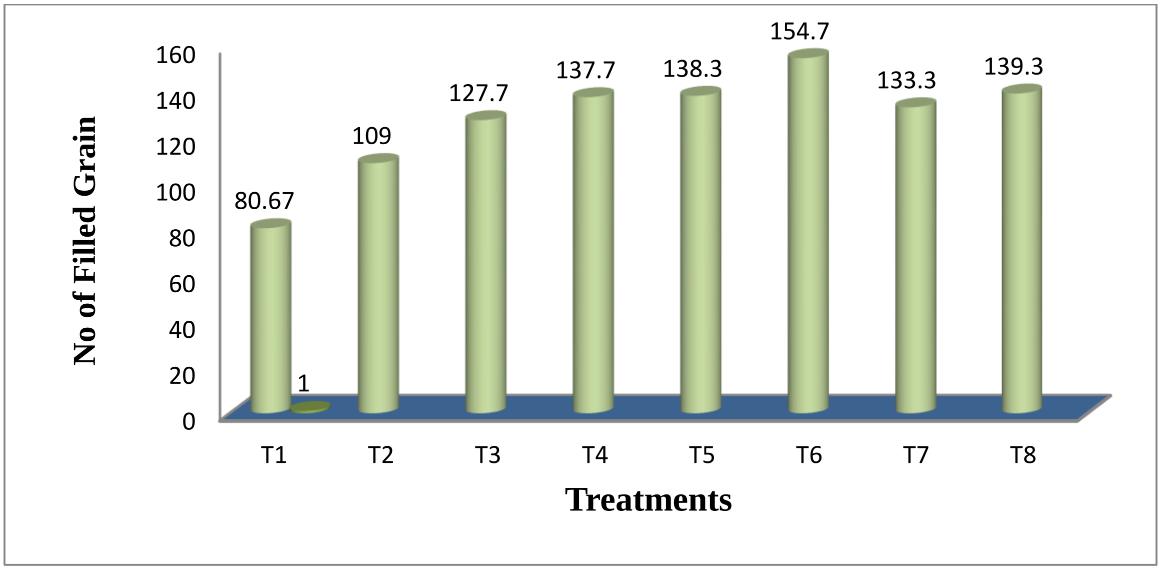

Figure 6: Effects of urea super granule (USG) and NPK briquettes on filled grains/panicle of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.5.3 Number of unfilled grains/panicle

Application of Urea super granule (USG) and NPK briquettes showed significant variation on production of unfilled grains/panicle (Figure 7). It was found that number of unfilled grains/panicle were statistically significant. The maximum number of unfilled grains/panicle (41.57) was obtained in the T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The second highest unfilled grains/panicle (34.40) was obtained in the T_7 (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment. However unfilled grains/panicle did not differ significantly in T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills. and T_5 (3 briquettes of NPK of 2.4g weight in between 4 hills. treatments. The minimum number of unfilled grains/panicle (11.43) was obtained in the T_3 (1 briquette of NPK of 2.4g weight in between 4 hills. treatment.

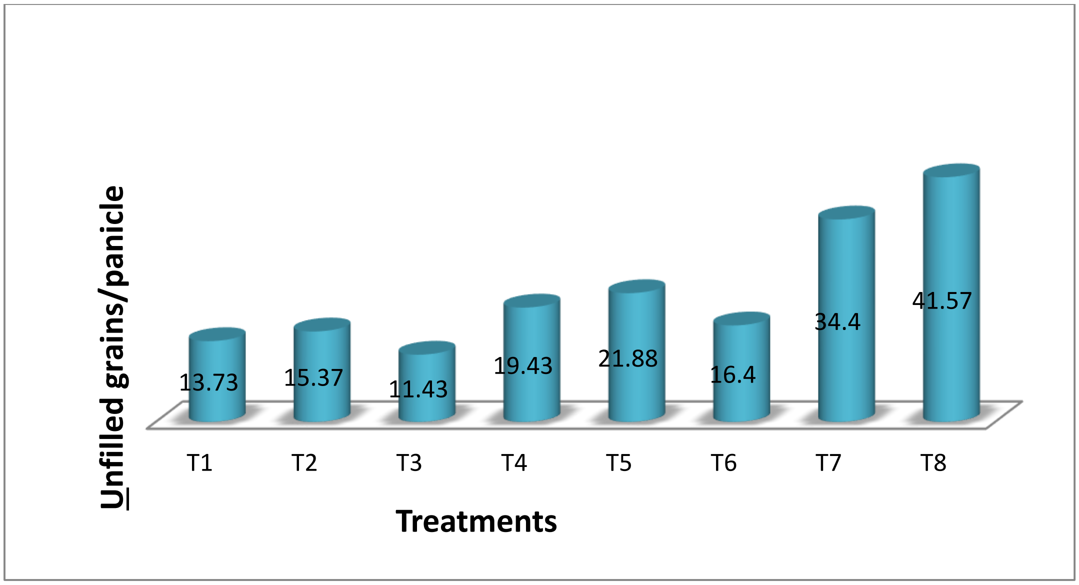

Figure 7: Effects of urea super granule (USG) and NPK briquettes on unfilled grains/panicle of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

Table: 5. Effects of urea super granule(USG) and NPK briquettes on 1000 grain weight (gm), grain yield (t/ha), straw yield (t/ha), biological yield (t/ha) and harvest index (%)of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

Treatments	1000 grain weight (gm)	Grain Yield(t/ha)	Straw Yield(t/ha)	Biological yield (t/ha)	Harvest index (%)
T_1	32.47 bc	4.093 e	5.463 f	9.55de	42.82 ef
T_2	30.48 c	5.467 d	5.097 g	10.55 d	51.75b
T_3	35.44 a	5.090 d	6.647 c	11.73 c	43.39 e
T_4	34.66 a	6.037 c	4.780 h	10.81 d	55.78 a
T_5	35.37 a	5.910 c	7.083 b	12.99 b	45.49 d
T_6	35.40 a	7.037 a	7.773 a	14.8 a	47.53 c
T_7	35.36 a	6.540 b	6.073 d	12.61 b	51.86 b
T_8	33.43 ab	6.127 bc	5.830 e	11.95 c	51.21 b
LSD(.05)	NS	.429	.127	.912	.581
CV	3.54	4.23	1.10	6.07	9.05

(NS = Non Significant)

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.6 1000-grain weight (gm)

1000-grain weight was found to be statistically insignificant in all of the treatments used in the experiment (Figure 8). The maximum 1000-grain weight (35.44) was obtained from the T_3 (1 briquette of NPK of 2.4g weight in between 4 hills + SZn) treatment and minimum 1000-grain weight (30.48) was obtained in the T_2 (RFD for Boro rice) treatment Table 5. The result fairly agreed with the findings of Rahman (2003) and Azad *et al.* (1995) who found that the level of nutrient didn't influence the weight of 1000-grain weight significantly which is dissimilar with the findings of Mohaddesi *et al*. (2011) that 1000 grain weight had significant effect with increasing nutrient levels.

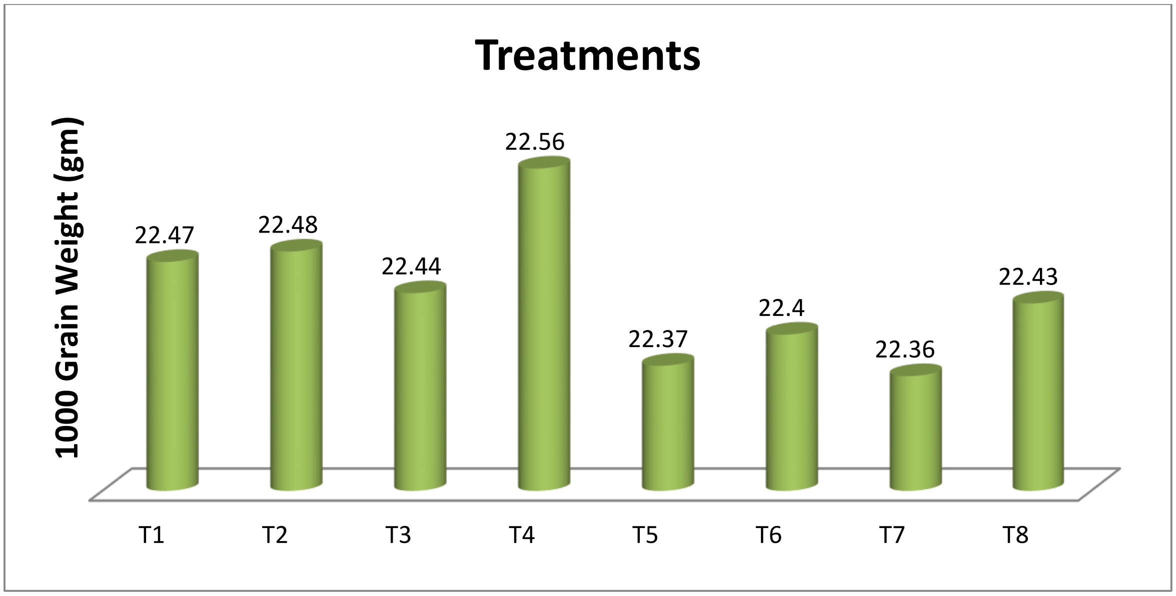

Figure 8: Effects of urea super granule (USG) and NPK briquettes on 1000-grain weight (gm) of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.7 Grain yield (t/ha)

The grain yield of BRRI dhan28 responded significantly to the grain yield ranged from 7.03 t/ha to 4.09 t/ha. Figure 9 shows the effects of different treatments on grain yield (t/ha). The highest grain yield (7.03 t/ha) was obtained in the T_6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. However Grain yield did not differ significantly in T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills), T_7 (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn), T_5 (3 briquettes of NPK of 2.4g weight in between 4 hills) treatments. The lowest grain yield (4.09 t/ha) was obtained in the T_1 control (no nutrient fertilizer) treatment.

Idris and Matin (1990) reported that application of nutrient increased the yield of rice which supports the results.

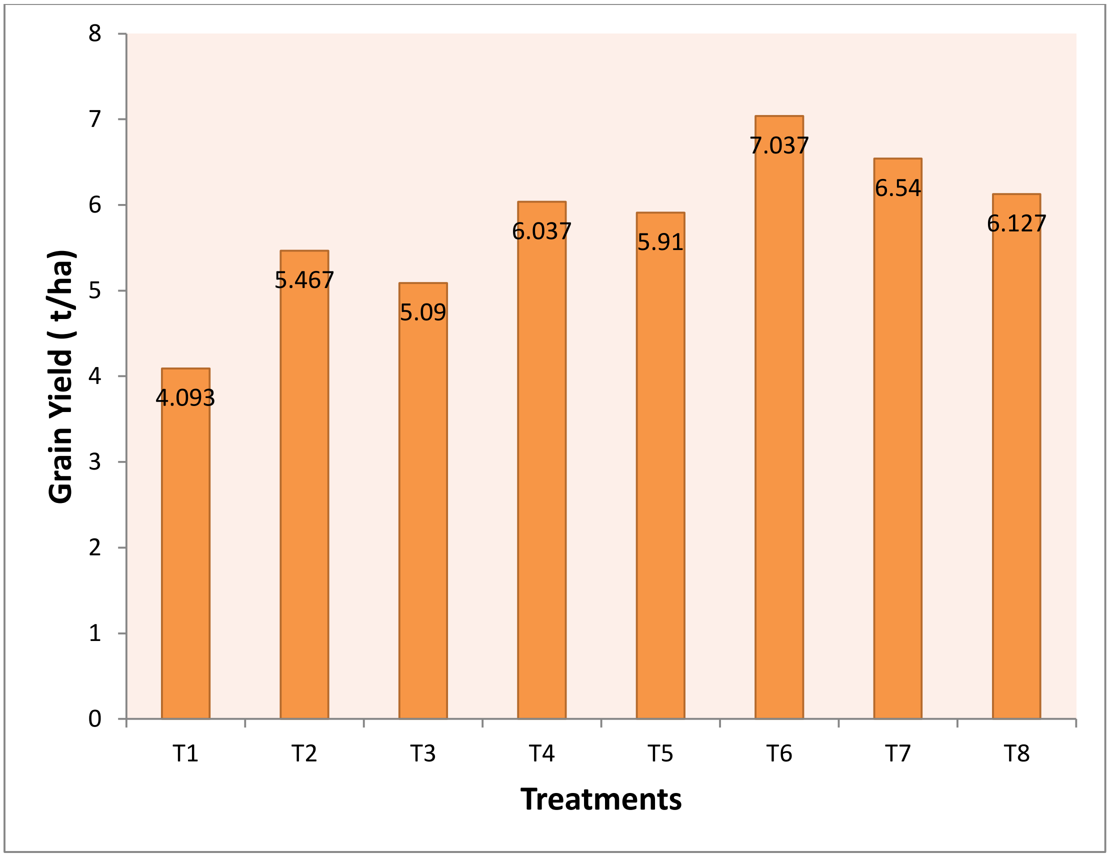

Figure 9: Effects of urea super granule (USG) and NPK briquettes on grain yield (t/ha) **of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.**

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.8 Straw yield (t/ha)

Straw yields of BRRI dhan28 also responded significantly to different treatments which are under study. The yields of straw ranged from 7.77 t/ha to 5.46 t/ha, Figure 10 shows the effects of different treatments on straw yield (t/ha). The highest straw yield (7.77 t/ha) was obtained in the T_6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments. The lowest straw yield (4.78 t/ha) was obtained in the T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills + SZn) treatment.

Elbadry *et al.* (2004), Meena *et al.* (2003) and El-Rewainy (2002) observed similar view on straw yield due to nutrient application.

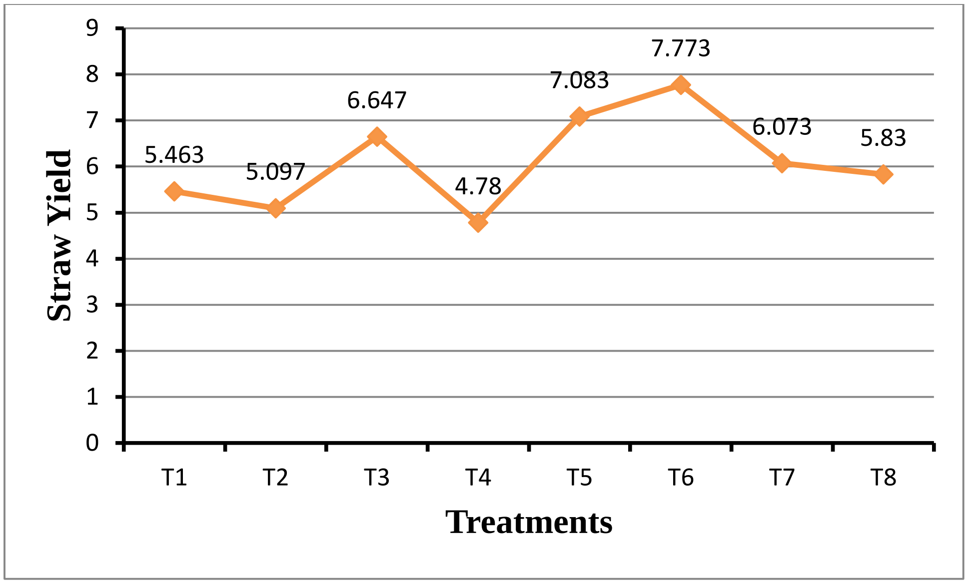

Figure 10: Effects of urea super granule (USG) and NPK briquettes on straw yield (t/ha) **of boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment.**

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.9 Biological yield (t/ha)

Table 5 shows the effects of different treatments on biological yield. Biological yield was significantly influenced by the application of urea super granule (USG) and NPK briquettes. The highest biological yield (14.8 t/ha) was obtained in the T_6 (1 Urea super granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment followed by T_7 (2 Urea super granule of 2.7g weight in between 4 hills + PKSZn), T_3 (1 briquette of NPK of 2.4g weight in between 4 hills + SZn), T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) treatment. The lowest biological yield (9.55 t/ha) was obtained in the T_1 control (no nutrient fertilizer) treatment. The result agreed with the findings of Ahmed *et al.* (2005) who observed the significant effect of nutrient on biological yield (t ha^{-1}) of rice.

4.10 Harvest Index

Harvest index (HI) is the ratio of seed yield to total above ground plant yield. Effect of nutrient sources exerted significant variation on harvest index Table 5. Harvest index was highest (55.78%) at T_4 (2 briquettes of NPK of 2.4g weight in between 4 hills + SZn) treatment which is not statistically similar with the T_2 (RFD for Boro rice) treatment and the lowest harvest index (42.82%) was obtained from no nutrient treatment (T_1).

4.11 pH of Post-Harvest Soils

A significant variation was recorded in post-harvest soil pH due to the application of different levels of nitrogen for BRRI dhan28 cultivation Table 6. The highest pH of post-harvest soil (6.2) was found from T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills. which was statistically identical with others. The lowest pH of post-harvest soil (5.5) was recorded from T_1 control (No fertilizer).

Table 6: Effects of urea super granule (USG) and NPK briquettes on pH of post-harvest soils of boro rice (BRRI dhan28).

Treatments	pH of Post-Harvest Soils
T_1	5.5 e
T_2	5.6 d
T_3	5.6 d
T_4	5.7 cd
T_5	5.6 d
T_6	5.8 b
T_7	6 b
T_8	6.2 a
Initial soil organic carbon	**5.8**
$LSD_{0.05}$	NS
CV%	0.18

(NS = Non Significant)

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.12 Organic carbon of post-harvest soil

The value of organic carbon of the post-harvest soils was not differ significantly due to the application of urea super granule (USG) and NPK briquettes on BRRI dhan28 cultivation. The organic carbon remains almost similar among all the eight treatments. The ranges of organic carbon are shown at the Table 7.

Table 7: Effects of urea super granule (USG) and NPK briquettes on Organic carbon of post-harvest soil of boro rice (BRRI dhan28).

Treatments	Organic carbon of Post-Harvest Soils
T_1	0.61
T_2	0.60
T_3	0.63
T_4	0.63
T_5	0.64
T_6	0.60
T_7	0.60
T_8	0.61
Initial soil organic carbon	**0.60**
$LSD_{0.05}$	NS
CV%	3.41

(NS = Non Significant)

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for boro rice.

T_3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

4.13 Organic matter of post-harvest soil

Table 8 is showing the effects of urea super granule (USG) and NPK briquettes on organic matter status of post-harvest soils. It was found that organic matter status of post-harvest soil statistically insignificant. The organic matter remains almost similar among all the eight treatments.

Table 8: Effect of urea super granule (USG) and NPK briquettes on organic carbon of post- harvest soils of boro rice (BRRI dhan28).

Treatments	**Organic matter of Post-Harvest Soils**
T_1	1.05
T_2	1.07
T_3	1.07
T_4	1.07
T_5	1.03
T_6	1.04
T_7	1.07
T_8	1.8
Initial soil organic carbon	**1.03**
$LSD_{0.05}$	NS
CV%	3.46

(NS = Non Significant)

T1: No fertilizer

T2: RFD (Recommended Fertilizer Dose) for boro rice.

T3: 1 briquette of NPK of 2.4g weight in between 4 hills + SZn.

T4: 2 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T5: 3 briquettes of NPK of 2.4g weight in between 4 hills + SZn.

T6: 1 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T7: 2 Urea super granule of 2.7g weight in between 4 hills + PKSZn.

T8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

CHAPTER V

SUMMARY AND CONCLUSION

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 November 2016 to May 2017, with a view to evaluating the effects of urea super granule (USG) and NPK briquettes on the growth and yield of BRRI dhan28 at boro season under the Modhupur Tract (AEZ-28). The soil was silt loam in texture having pH 5.8, organic matter content 1.187%, total N 0.08%, available P 19.8 (mg kg^{-1}), Exchangeable K (cmol kg^{-1}) 0.12, available S (mg kg^{-1}) 14.40, and CEC (cmol kg^{-1}) 17.9.

There were altogether eight treatment combinations consisting of different source of N comprising urea super granule (USG) and NPK briquettes.

T_1: No fertilizer

T_2: RFD (Recommended Fertilizer Dose) for Boro rice.

T_3: 1 granule of NPK of 2.4g weight in between 4 hills + SZn.

T_4: 2 granule of NPK of 2.4g weight in between 4 hills + SZn.

T_5: 3 granule of NPK of 2.4g weight in between 4 hills + SZn.

T_6: 1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn.

T_7: 2 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn.

T_8: RFD + 1 Urea super granule of 2.7g weight in between 4 hills.

The experiment was laid out in a Randomized Complete Block Deign (RCBD) with three replications. The total number of unit plots was 24 and the size of unit plot was 4 m × 2.5 m. All the treatments except T_1, $T_{3,}$ T_4 and T_5 received 36 kg P and 72 kg K ha^{-1} from TSP and MoP, respectively. In $T_{3,}$ T_4 and T_5 treatments, P and K were supplied from NPK briquettes. . Sulphur 36 kg ha^{-1}

and zinc 6.4 kg ha^{-1} were applied to all plots (except T_1) as basal dose from gypsum and zinc oxide, respectively. Forty-five day old seedlings were transplanted in the experimental plots maintaining three seedlings per hill and plant spacing of 20 cm × 20 cm. PU was applied in three equal splits. The first dose of PU was applied 10 days after transplanting (DAT), the second dose was added as top dressing 35 DAT (active tillering stage) and the third dose was top-dressed 55 DAT (panicle initiation stage. USG and NPK briquettes were applied at 10 DAT and the briquettes were placed at 8-10 cm depth between four hills at alternate rows. Before application of N fertilizers, the water in the rice plots was drained out. Different intercultural operations such as irrigation, weeding, pest control, etc. were done as and when required. The crop was harvested at full maturity. Data on plant height, panicle length, number of effective tillers/hill, number of filled grain/panicle, unfilled grain/panicle, 1000 grain weight, grain yield, straw yield, biological yield and harvest index were recorded. One additional harvest was carried out in each plot at panicle initiation stage. The harvest comprised of 25 hills (5 hills x 5 hills) covering an area of 1 m^2. The sun dried straw weight was expressed in kg ha^{-1}. Data on different growth and yield parameters were recorded and analyzed statistically. At harvest, the tallest plant (100.4 cm) was recorded from T_7 treatment (2 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) which was significantly greater than that obtained from the rest of the treatments used in the experiment and the shortest plant (78.32 cm) was recorded from the control T_1 treatment (no fertilizer). The maximum length of Flag Leaf (34.43) was obtained in the T_4 (2 granule of NPK of 2.4g weight in between 4 hills + SZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. However the length of flag leaf did not differ significantly in T_5 (3 granule of NPK of 2.4g weight in between 4 hills + SZn) and T_7 (2 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatments. The minimum length of flag leaf (15.33) was obtained in the T_1 control (no fertilizer) treatment. The highest number of effective tillers/hill (17.33) was obtained in the T_7 (2 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatment and T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) which was significantly greater than that obtained from the rest of the treatments used in the experiment. The minimum number of effective tillers/hill (9) was obtained in the T_1 control (no fertilizer) treatment. The number of filled grains/panicle varied from 80.67 to 157.7 with the highest value in T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The minimum number of filled grains/panicle (80.67) was obtained in the T_1 control (no nutrient fertilizer) treatment. The maximum number of unfilled grains/panicle (41.57) was obtained in the T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The minimum number of unfilled grains/panicle (11.43) was obtained in the T_3 (1 granule of NPK of 2.4g weight in between 4 hills + SZn) treatment. The maximum 1000-grain weight (35.44) was obtained from the T_3 (1 granule of NPK of 2.4g weight in between 4 hills + SZn) treatment and minimum 1000-grain weight (30.48) was obtained in the T_2 (RFD (Recommended Fertilizer Dose) for Boro rice treatment. The highest grain yield (7.03 t/ha) was obtained in the T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The lowest grain yield (4.09 t/ha) was obtained in the T_1 control (no nutrient fertilizer) treatment. The yields of straw ranged from 7.77 t/ha to 4.78 t/ha shows the effects of different treatments on straw yield (t/ha). The highest straw yield (7.77 t/ha) was obtained in the T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) treatment which was significantly greater than that obtained from the rest of the treatments. The lowest straw yield (4.78 t/ha) was obtained in the T_4 (2 granule of NPK of 2.4g weight in between 4 hills + SZn) treatment.

The present study was conducted to improve our understanding of rice responses to the application of urea super granule (USG) and NPK briquettes. Our results indicated beneficial effects of urea super granule (USG) and NPK briquettes. Application of urea super granule (USG) and NPK briquettes have a profound effect on effective tillers/hills, 1000 grain weight, filled grain/panicle, unfilled grain/panicle, grain yield, straw yield & biological yield.

The overall results indicate that the highest grain yield (7.03 t/ha)of BRRI dhan28 was found in the treatment T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn) which was significantly greater than that obtained from the rest of the treatments used in the experiment. On the contrary, the maximum number of total grains/panicle (180.87) was obtained in the T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills), and also the maximum number of unfilled grains/panicle (41.57) was obtained in the T_8 (RFD + 1 Urea super granule of 2.7g weight in between 4 hills) treatment which was significantly greater than that obtained from the rest of the treatments used in the experiment. The treatment T_6 also demonstrated the highest straw yield (7.777 t/ha). Therefore, the treatment T_6 (1 Urea Super Granule of 2.7g weight in between 4 hills + PKSZn), can be recommended for successful cultivation of boro rice (BRRI dhan28).

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CHAPTER VI
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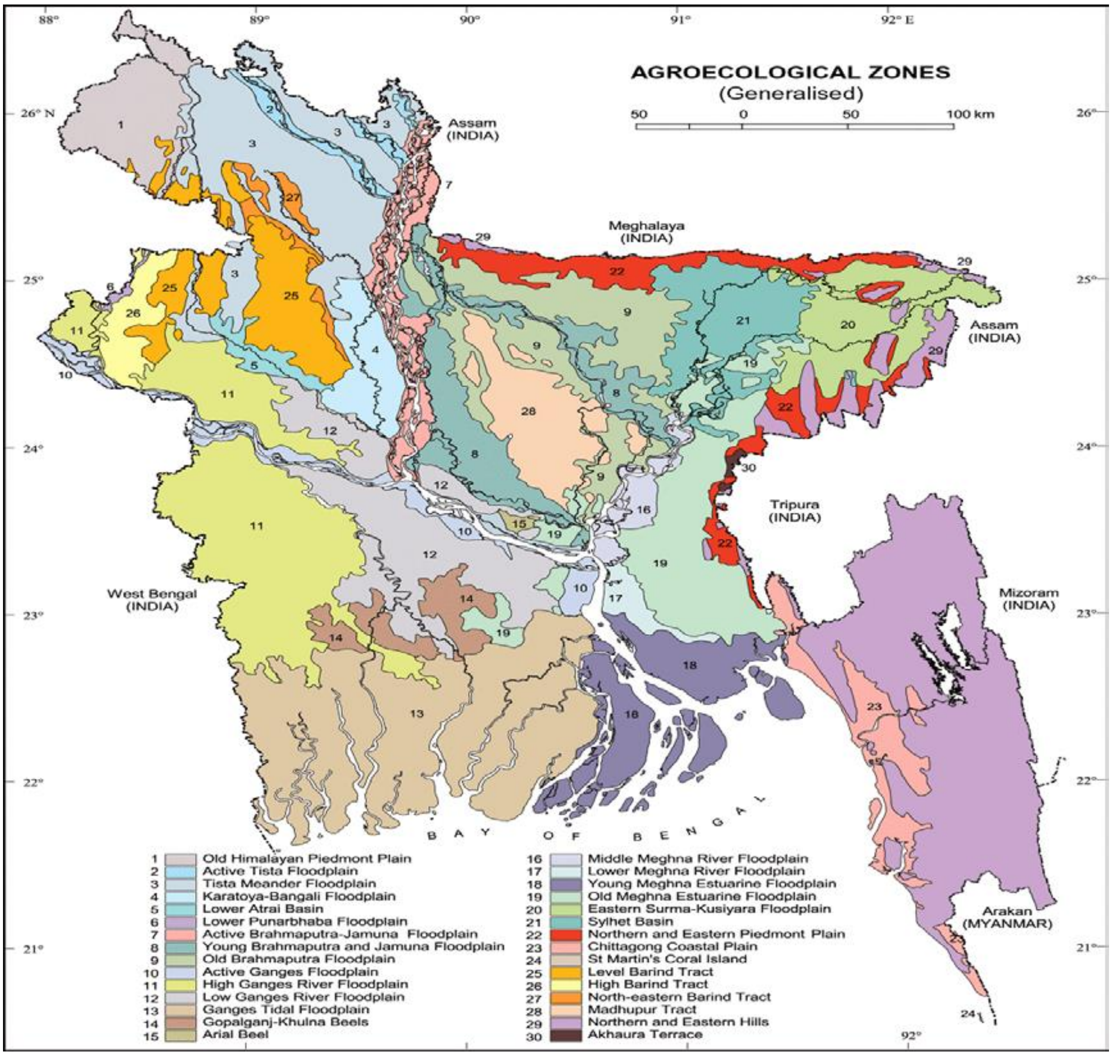
APPENDICES

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

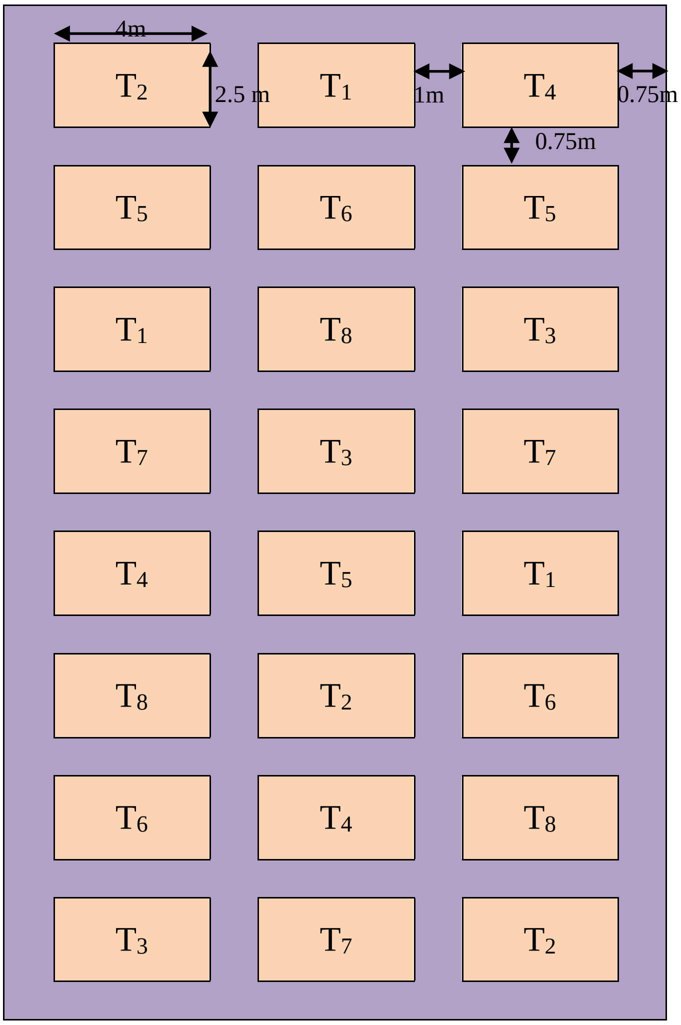


Appendix II. Monthly average temperature and total rainfall of the experimental site during the period from December 2016 to May 2017

Month	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
December,	54.80	25.50	6.70	16.10	0.0
January, 2017	46.20	23.80	11.70	17.75	0.0
February, 2017	37.90	22.75	14.26	18.51	0.0
March, 2017	52.44	35.20	21.00	28.10	20.4
April, 2017	65.40	34.70	24.60	29.65	165.0
May, 2017	68.30	32.64	23.85	28.25	182.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Layout of the experiment field



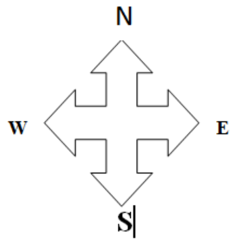


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Plate no. 5. Field view of experimental field after seedling establishment

Plate no. 6. Irrigation and management practices

Plate no. 7. Pest controlling measures.

Plate no. 8. Crop harvesting.

Plate no. 9. Harvested crops at ripening stage.

Plate no. 10. Post-harvest sample collection from the experimental plot.