EFFECT OF NPK BRIQUETTE FERTILIZATION ON THE GROWTH AND YIELD OF AROMATIC RICE VARIETY BRRI dhan70

MST. DILRUBA YEASMIN

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

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BY

MST. DILRUBA YEASMIN

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Approved by:

Prof. Dr. Alok Kumar Paul **Supervisor**	**Prof. Mst. Afrose Jahan** **Co-supervisor**

Prof. 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 '***Effect of NPK Briquette Fertilization on the Growth and Yield of Aromatic Rice Variety BRRI dhan70***' submitted to the Department 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****, embodies the results of a piece of bona fide research work carried out by* ***MST. DILRUBA YEASMIN****, Registration No.* ***16-07538*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: December, 2017
Dhaka, Bangladesh

Prof. Dr. Alok Kumar Paul
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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EFFECT OF NPK BRIQUETTE FERTILIZATION ON THE GROWTH AND YIELD OF AROMATIC RICE VARIETY BRRI dhan70

ABSTRACT

The experiment was conducted during the period of July to November, 2017 in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to assess the effect of NPK briquette fertilization on the growth and yield of aromatic rice variety BRRI dhan70. The experiment comprised of the following 7 treatments as- T_0: Control i.e. no fertilizer; T_1: 100% RFD; T_2: 120% RFD; T_3: 80% RFD; T_4: 1 NPK briquette in between 4 hills and T_5: 2 NPK briquette in between 4 hills and T_6: 80% RFD + 1 NPK briquette in between 4 hills. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different yield contributing characters, yield and characteristics of post-harvest soil. Statistically significant variation was recorded for different treatments. During harvest, the longest plant (126.06 cm) was recorded from T_6 treatment, while the shortest plant (110.68 cm) from T_0. The maximum number of effective tillers hill^{-1} (22.80) was observed from T_6 treatment, whereas the minimum number (15.40) from T_0 treatment. The longest panicle (26.63 cm) was recorded from T_6 treatment, while the shortest panicle (19.50 cm) from T_0 treatment. The maximum number of filled grains panicle^{-1} (120.60) was observed from T_6 treatment, while the minimum number (101.60) from T_0 treatment. The highest grain yield (4.72 t ha^{-1}) was recorded from T_6 treatment, while the lowest grain yield (2.04 t ha^{-1}) from T_0 treatment. In post-harvest soil, the highest total N (0.067%) was found from T_6 treatment, while the lowest soil total N (0.021%) from T_0 treatment. The highest available P (39.32 ppm) was observed from T_6 treatment, whereas the lowest available P (14.40 ppm) from T_0 treatment. The highest exchangeable K (0.177 meq/100 g soil) was observed from T_6 treatment, while the lowest exchangeable K (0.123 meq/100 g soil) from T_0 treatment. Applications of T_6 treatment (80% RFD + 1 briquette NPK) was the superior among the other treatments in consideration of yield contributing characters and yield of aromatic rice variety BRRI dhan70.

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Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.), belongs to the family Poeaceae, is the most important food in tropical and subtropical regions (Singh *et al*., 2012). The term "rice" refers to the species *Oryza sativa* L. and *Oryza glaberrima* Steud. *Oryza glaberrima*, also known as "African rice", is native to sub-Saharan Africa, where it is still grown, but due to its lower yield potential progressively replaced by *Oryza sativa* (Linares, 2002). It is grown in more than a hundred countries with a total area of about 160 million hectares, producing more than 700 million tons every year (IRRI, 2013). There are about 13 million farm families, who grow different types of rice, which includes traditional, modern or hybrid rice varieties. It is the grain that has shaped the culture, diet, and economies of billions of people in the world (Farooq *et al.,* 2009).

Almost the entire rice produced is *Oryza sativa*, which is one of the three mega-crops (rice, maize, and wheat) on which more than half the world's population relies as main staple food, grown in wide range of climatic zones, to nourish the mankind and is particularly important in Asia, where approximately 90% of world's rice is produced and consumed (Maclean *et al.,* 2002; Khush, 2005; Zeigler and Barclay, 2008; Wassmann *et al.,* 2009). Bangladesh ranks 4^{th} in both area and production and 6^{th} in the production of per hectare yield of rice (Sarkar *et al*., 2016). In Bangladesh, people also consumed rice as staple food and it constituted about 90% of the total food grain production (Huda, 2001). The geographical, climatic and edaphic conditions of Bangladesh are favorable for year round rice cultivation. There are several major rice growing ecosystems in Bangladesh. Of the three types of rice are *aus* (early monsoon rice), *aman* (monsoon rice) and *boro* (dry/winter season rice) and the *boro* rice alone contributed the highest share of total production since 1998-99 to date. *Aman* season rice accounts for nearly 51% of total land, followed by *boro* and *aus* season rice which is 40% and 9%, respectively.

The area and production of total rice in Bangladesh is about 11.39 million hectares of land occupying 72.24% of total cropped area, with annual production of 34.71 million tons (BBS, 2017). The country is said to have among the highest per capita consumption of rice is about 170 kg annually (BBS, 2017) and its food security and economy largely depend on good harvests year after year. In the last three to four decades, great efforts in rice research and farming innovations were made to boost rice production, and it has increased to about 48 million tons in 2009 from about 17 million tons in 1970. Scientists, extension agents, and farmers worked hard to achieve this success. However, challenges still lie ahead as Bangladesh becomes more densely populated and the cultivable land is reducing year after year due to urbanization, industrialization and different works.

The population of Bangladesh is growing by two million every year and may increase by another 30 million over the next 20 years. Population growth in Bangladesh demands a continuous increase of rice production and the highest priority has been given to produce more rice (Bhuiyan, 2004). Thus, Bangladesh will require additional about 27.26 million tons of rice for the year 2020 (BRRI, 2016). Population growth demands a continuous increase in rice production in Bangladesh and it needs to be increased by 53.3% (Mahamud *et al.*, 2013). In Bangladesh, the average yield of rice is about 2.92 t ha^{-1} (BBS, 2017) which is very low compared to other rice growing countries of the World, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}) (FAO, 2014). In some years and in some seasons it is noticed that the level of food security and hunger rises due to crop loss, low rice yield. Therefore, increase of *boro* rice production would be a significant possible way to overcome food deficiency in the country. Thus, the production of dry season irrigated rice has a predominant importance for national food security (Fujita, 2004). Therefore, attempts should be taken to increase the yield per unit area through use of NPK briquette fertilization.

Rice yields are either stagnating or declining in post green revolution era for various reasons but the major are attributed to prevalence of local varieties instead of high yielding varieties and without practicing proper management practices (Singh *et al*., 2012). Among the production factors affecting crop yield, source is the single most important factor that plays a dominant role in yield increase if other production factors are not limiting. Emergence of widespread multi-nutrient deficiencies causing serious stagnation in yields and declining productivity of various rice ecosystems (Mangala, 2006). Excess use of fertilizer nutrients implies increase of cost and decreases of returns and risk of environmental and soil pollution (Sharma *et al.* 2003). Judicious use of fertilizer is a key factor in rice based production system which can increase crop yield and reduce production cost. NPK briquette is a mixture of urea, TSP and MOP which helps to reduce the loss of nutrients in flooded condition. So, it is helpful for tidal flooded ecosystem. In 100 kg NPK briquette have 50 kg urea, 20 kg TSP and 30 kg MoP (Islam *et al*., 2011). Farmer in Vitenam and Combodia obtained 25% higher yields with deep placement of NPK briquettes over the broadcasting of fertilizers and in Bangladesh yield of rice would be increased by 15-25%, while expenditure on commercial fertilizer was decreased by 24-32% when fertilizers briquettes were used as a source of N, P and K (IFDC, 2007). Therefore, it is necessary to make a comparative study of USG and NPK briquette on the performance of rice variety.

Based on the above all mentioned situation the present study was conducted for fulfilling the following objectives:

1. To evaluate the efficiency of NPK briquette for increasing the yield of aromatic rice variety BRRI dhan70.
2. To find out the optimum doses of NPK briquette on the growth, development and yield of aromatic rice variety BRRI dhan70.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Rice has remarkable adaptability to different environmental conditions as is evident from its worldwide distribution. Many researchers at home and abroad investigated various aspects of successful rice production. Sole and combined use of inorganic recommended fertilizers in different forms increase plant growth, yield attributes and yield of rice. Experimental evidences that the use of recommended dose of fertilizers (nitrogen, phosphorus, potassium, sulphur and zinc) have an intimate effect on the yield and yield attributes of rice. But research works related to recommended fertilizer doses of fertilizers from different forms of application sources are limited in Bangladesh context. Some related research findings on the agronomic performances of rice varieties as affected by different fertilizer management have been reviewed in this chapter under the following headings-

2.1 Effect of recommended doses of chemical fertilizers on rice

2.1.1 Effect of nitrogen

Rahman *et al.* (2016) conducted an experiment to evaluate the effect of levels of USG and depth of placement on the growth of T. *aman* rice. USG levels showed non-significant effect on plant height. They also reported that plant height was found highest when USG was applied with BRRI dhan48 and all the characters showed lowest value when absolute control with BRRI dhan55.

Lukman *et al*. (2016) reported that the combined application of cow dung and NPK fertilizer significantly increased most of the results obtained with regards to locations compared to the control plots. The growth and yield parameters of rice considered were significantly affected by the treatments except one thousand grain weight. Application of 8 t ha^{-1} of cowdung in combination with 400 kg ha^{-1} NPK 20:10:10 gave the highest grain yield (5.77 t ha^{-1}) at Sokoto and it is recommended that application of 12 t ha^{-1} of cowdung in combination with 300 kg ha^{-1} NPK 20:10:10 resulted in the best soil nutrient enrichment and yield of rice in Sokoto and Talata Mafara.

Murthy *et al*. (2015) conducted an experiment with an objective to revise the existing fertilizer doses of major nutrients in Krishna Godavari delta regions of Andhra Pradesh. Grain yield was increased by 11.5% and 6.3% due to increase in recommended dose of N from 100% (120 kg ha^{-1}) to 125% and 150%.

Naznin *et al*. (2013) investigate the effects of prilled urea (PU), urea super granule (USG) and NPK briquette on NH4- N concentration in field water, yield and nitrogen (N) use efficiency (NUE) of BR22 rice under reduced water conditions and reported that the highest grain yield of 3.93 t ha^{-1} from 104 kg N ha^{-1} as USG and the lowest value of 2.12 t ha^{-1} was obtained from control. The N use efficiency was increased when the N was applied as USG. The overall results revealed that application of USG and NPK briquette may be practiced for obtaining better yields in addition to increasing the efficiency of N fertilizer.

Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest number of panicle, number of grains $panicle^{-1}$, 1000-grain weight, straw yield and harvest index.

Duhan and Singh (2002) reported that the rice yield and uptake of nutrients increased significantly with increasing N levels. Moreover, the application along with various green manures (GM) showed additive effect on the yield and uptake of micronutrients. Under all GM treatments, the yield and uptake were always higher with 120 kg ha^{-1} than with lower level of nitrogen.

Angayarkanni and Ravichandran (2001) conducted a field experiment in Tamil Nadu, India from July to October 1997 to determine the best split application of 150 kg N ha^{-1} for rice cv. IR20. 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 highest grain (6189.4 kg ha^{-1}) and straw (8649.6 kg ha^{-1}) yields, response ratio (23.40) and agronomic efficiency (41.26).

Munnujan *et al*. (2001) treated 4 levels of nitrogen fertilizer (0, 40, 80, and 160 kg ha^{-1}) application at three levels each planting density (20, 40 and 80 hill m^{-1}) and conducted that the highest grain yield (3.8 t ha^{-1}) was obtained with 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

Pulley *et al*. (2000) observed that increased yield associated with application of nitrogen stage, although booting stage nitrogen application had no effect or shoot growth or nitrogen uptake. These preliminary results suggested a single application of nitrogen is sufficient to maintain healthy rice growth, alleviating the need for additional N application after flooding. Rice may be responded to N applied as late as booting, but only when the rice is N limited and not severely N stressed.

BRRI (2000) reported that the grain yield was linearly increased with increasing nitrogen rates. Castro and Sarker (2000) conducted field experiment to see the effects of N applications as basal (80, 60, and 45kg N ha^{-1}) and top dressing (10, 30 and 45 kg ha^{-1}) on the yield and yield components of Japonica rice and obtained high effective tiller, percentage of ripened grains and high grain yields from 45 kg N ha^{-1} (basal) and 45 kg N ha^{-1} (top dressing). Singh *et al.* (2000) stated that each increment dose of N significantly increased grain and straw yields of rice over its preceding dose. Consequently the crop fertilized with 100 kg N ha^{-1} gave maximum grain yield (2647 kg ha^{-1}).

Bellido *et al*. (2000) evaluate a field experiment with 4 levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and reported that the amount of total dry matter was significantly greater at the N fertilizer rates of 100 and 150 kg nitrogen ha^{-1}.

2.1.2 Effect of phosphorus

Tang *et al*. (2011) conducted a field experiment on winter wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) crop rotations in Southwest China to investigate phosphorus (P) fertilizer utilization efficiency, including the partial factor productivity (PFP), agronomic efficiency (AE), internal efficiency (IE), partial P balance (PPB), recovery efficiency (RE) and the mass (input–output) balance. This study suggests that, in order to achieve higher crop yields, the P fertilizer utilization efficiency should be considered when making P fertilizer recommendations in wheat–rice cropping systems.

Islam *et al*. (2010) conducted a field experiment with five phosphorus rates (0, 5, 10, 20 and 30 kg P ha^{-1}) with four rice genotypes in Boro and T. Aman season. Phosphorus rates did not influence grain yield irrespective of varieties in T. aman season while in Boro season P response was observed among the P rates. Application of P @ 10 kg ha^{-1} significantly increased the grain yield. But when P was applied @ 20 and 30 kg P ha^{-1}, the grain yield difference was not significant. The optimum and economic rate of P for T. Aman was 20 kg P ha^{-1} but in Boro rice the optimum and economic doses of P were 22 and 30 kg ha^{-1}, respectively. Hybrid entries (EH_1 and EH_2) used P more efficiently than inbred varieties. A negative P balance was observed up to 10 kg P ha^{-1}.

Dunn and Stevens (2008) conducted a field experiment to evaluate the effect of polymer coating of phosphate fertilizer on rice yield. Three rates of phosphate fertilizer, including polymer coated and non-coated, were compared to an untreated check. Net return was calculated based on crop price and input costs. At the rate of 25 lb/acre P_2O_5 rate the polymer coated treatments produced greater yields than equivalent non coated treatments.

Li *et al.* (2007) conducted an experiment to evaluate the contributions of rice root morphology and phosphorus uptake kinetics to P uptake by rice from iron phosphates. The Fe-P treatment significantly decreased plant dry weight, P uptake per plant, and P concentration in plant dry matter of all cultivars in comparison with the control plants.

Nair and Rajasree (2004) conducted a field experiment to assess comparative efficiency of super phosphate and PR (34/74) at different levels in the yield characters and composition of rice. The treatments were 30 and 45 kg P_2O_5 ha^{-1} in the form of superphosphate and PR (34/74) with and without organic matter. The results showed that high grade phosphate rock (M, 34/74) with organic manure performed well and were followed by PR (34/74) with iron pyrites and green manure. Thus, PR (34/74) performed well with organic matter, FeS_2 and green manure in deciding growth and yield of rice. Higher contents of N, P, K, Ca and Mg of grain and straw were obtained at higher levels of 45 kg P_2O_5 ha^{-1} treatment.

Sahrawat *et al*. (2001) conducted a field experiment for six years (1993-1998) to determine the response of four promising upland rice cultivars with 0, 45, 90, 135, and 180 kg/ha as triple super phosphate (TSP). Only once used in 1993 and its residual value in 1994, 1995, 1996 and 1998 stated that grain yields of the rice cultivars were significantly increased by fertilizer P in 1993 and by the fertilizer P residues in the subsequent years although the magnitude of response decreased rapidly with time since the fertilizer was not applied.

2.1.3 Effect of potassium

Wang (2011) conducted a field experiment to study the effects of N, P and K fertilizer application on grain yield, grain quality as well as nutrient uptake with four levels of nitrogen (N), phosphorus (P) and potassium (K) fertilizers. The results revealed that the application of N, P and K fertilizer significantly increased grain yield, and the highest yield was found under the combined application of N, P and K fertilizer.

Wan *et al*. (2010) evaluated the effects of application of fertilizer, pig manure (PM), and rice straw (RS) on rice yield, uptake, and usage efficiency of potassium, soil K pools, and the non-exchangeable K release under the rice-rice cropping system. The field treatments included control (no fertilizer applied), NP, NK, NPK, and NK + PM, NP + RS, NPK + RS. The application of K fertilizer (NPK) increased grain yield by 56.7 kg ha^{-1} over that obtained with no K (NP).

Mostofa *et al*. (2009) carried a pot experiment in the net house at the Department of Soil Science, Bangladesh agricultural University, Mymensingh. Four doses of potassium (0, 100, 200, and 300 kg ha^{-1}) were applied. They observed that the yield contributing characters like plant height, tiller number, and dry matter yield were the highest in 100 kg ha^{-1} of K.

Muangsri *et al*. (2008) found that the effect of rice straw and rice hull in combination NPK fertilizer on yield of rice grown on Phimai soil series. The treatments consisted of the control, rice straw at the rate of 0.75, 1.5 and 3.0 g kg^{-1} soil in combination with NPK fertilizers, and rice hull at the rate of 0.75, 1.5, 3.0 and 4.5 g kg^{-1} soil in combination with NPK fertilizer. The results showed that the growth, yield and nutrient uptake of rice plant without fertilizer were the lowest. Yield of rice plant grown on the soil amended with rice straw in combination with NPK fertilizer showed to be higher than that of rice plant grown on the soil amended with only NPK fertilizer.

Krishnappa *et al.* (2006) reported that increasing K rates increased paddy yields. Potassium applied in split dressings were more effective than when applied at transplanting time. Application of potassium fertilizer with organic manure increased soil K availability, K content and the number of grains $panicle^{-1}$.

Sarkar and Singh (2002) conducted a field experiment to determine the effect of potassium and sulphur. They applied 110 kg N: 90 kg P: 70 kg K: 20 Kg S ha^{-1}. They observed that the number of tillers m^{-2}, 1000-grain weight, paddy and straw yield significantly increased with the application K with other fertilizer.

Natarajan *et al*. (2005) conducted an experiment during 2002-2003 with two rice hybrids, KRH2 and DRRHI in main plots and three levels of potassium (0, 40, and 80 kg ha^{-1}) in subplots to study the performance of rice hybrids with different K levels. The results clearly indicated that hybrid KRH2 performed superior with different levels of K.

Hong *et al*. (2004) conducted field experiments to investigate the potassium uptake, distribution and use efficiency of hybrid and conventional rice under different low K stress conditions. The grain yield and total k uptake by rice increased.

Shen *et al*. (2003) studied the effects of N and K fertilizer on the yield and quality of rice. Potassium fertilizer significantly improved all quality parameters and yield at 150 kg N ha^{-1} and equal amounts of K fertilizer applied to rice fields are optimum to obtain high yield.

Singh *et al.* (2000) evaluated the effect of levels of K application on rice at different places. Results indicated that K application significant enhanced the growth and yield of rice over no application. The highest grain and straw yields of rice was obtained at 90 kg K_2O ha^{-1} all the cropping seasons.

2.1.4 Effect of sulphur

The productivity of wheat–rice cropping system is declining over time despite adequate supply of major nutrients is reported by Singh and Singh (2014). It may be due to deficiency of nutrients like sulphur. A field experiment was conducted with treatments consisting of three levels of sulphate-sulphur (0, 15, 30 and 45 kg ha^{-1}) to study the sulphur balance and productivity in wheat-rice cropping sequence in a sandy clay loam soil. The agronomic efficiency and apparent sulphur recovery decreased with increase in levels of sulphate but the percent response increased with increasing sulphate application. Application of sulphur showed the positive sulphur balance, while it was negative for control.

Dixit *et al*. (2012) carried out a field experiment to study the effect of sulphur and zinc on yield, quality and nutrient uptake by hybrid rice grown in sodic soil and found that application of 40 kg S ha^{-1} recorded significantly high grain and straw yield, protein content and sulphur uptake.

A field experiment was carried out by Jawahar and Vaiyapuri (2011) at Experimental Farm, Annamalai University, Annamalai Nagar, Tamil Nadu, India to study the effect of sulphur and silicon fertilization on yield and nutrient uptake. The treatments comprised four levels of sulphur as 0, 15, 30 and 45 kg ha^{-1} and they observed highest yield and nutrient uptake of rice due to application 45 kg S ha^{-1}.

An experiment was conducted by Rahman *et al*. (2009) to know the effect of different levels of sulphur on growth and yield of BRRI dhan41 at Soil Science laboratory field of Bangladesh Agricultural University, Mymensingh during T. Aman season. There were eight treatments and they were T_0 (without S), T_1 (50% RFD of S), T_2 (75% RFD of S), T_3 (100% RFD of S), T_4 (125% RFD of S), T_5 (150% RFD of S), T_6 (175% RFD of S) and T_7 (200% RFD of S). All yield contributing characters like effective tillers $hill^{-1}$, filled grain $panicle^{-1}$, grain yield, straw yield, biological yield and 1000-grain weight except plant height and panicle length of BRRI dhan41 significantly increased due to different levels of S application.

Mrinal and Sharma (2008) carried a field trials during the kharif season to study the relative efficiency of different sources (gypsum, elemental sulphur and cosavet) and differnt levels of sulphur (0, 10, 20, 30 and 40 kg S ha^{-1}) in rice. The growth and yield of rice increased with the sulphur application. The grain and straw yield of rice increased significantly with increasing levels of sulphur up to 30 kg S ha^{-1}. The difference between sulphur sources was generally insignificant.

Alamdari *et al*. (2007) conducted a field experiment to observe the effect of sulphur (S) and sulfate fertilizers on zinc (Zn) and copper (Cu) by rice and reported that both Zn and Cu contents in the grain increased when N, P, K, S and Zn, Cu and Mn sulfate were applied together.

Bhuvaneswari *et al*. (2007) conducted a field experiment during kharif season, to observe the effect of sulphur (S) at different levels, i.e. 0, 20, 40 and 60 kg ha^{-1}, with different organics, each applied at 12.5 t ha^{-1}, on yield, S use efficiency. The results showed that rice responded significantly to the application of S and organics compared to the control. The highest grain (5065 kg ha^{-1}) and straw yield (7524 kg ha^{-1}) was found with 40 kg S ha^{-1}.

Basumatary and Talukdar (2007) carried out a field experiment at the Jorhat University, Assam, India to observe the direct effect of sulphur alone and in combination with graded doses of farmyard manure on rapeseed and also its residual effects on rice for yield, uptake and protein content. The N:S ratio in both crops progressively decreased with increasing sulphur levels up to 45 kg ha^{-1}. The lowest N:S ratio was observed upon treatment with 45 kg S ha^{-1} alone with 3.0 t/ha farmyard manure.

Islam *et al*. (2006) to evaluated the effect of gypsum (100 kg ha^{-1}) applied before planting, and at 30 and 60 days after planting, on the nutrient content of transplanted Aus rice (BR-2) in the presence of basal doses of N,P,K, fertilizers. Application of gypsum at different dates increased N, P, K, S, Ca and Mg contents progressively, whereas the Na content was found to decrease. The highest increase of N, P, K, S, Ca and Mg was obtained when the gypsum was applied at 30 days after planting. Synthesis of protein was accelerated with all the treatments of gypsum, and the content was much higher due to application of gypsum at 30 days after planting.

Biswas *et al*. (2004) reported the effect of S in different region of India. The optimum S varied between 30-45 kg ha^{-1}. Rice yields increased from 5 to 51%. Across the crops and regions the agronomic efficiency varied from 2 to 27%.

Chandel *et al*. (2003) conducted a field experiment to investigate the effect of sulphur nutrition on the growth and S content of rice and mustard grown in sequence with 4 S levels (0, 15, 30 and 45 kg ha^{-1}). They stated that increasing S levels in rice significantly improved yield attributes i.e. tiller number, leaf number, dry matter production and harvest index of rice up to 45 kg ha^{-1}.

Singh and Singh (2002) carried out a field experiment to see the effect of different nitrogen levels and S levels (0, 20 and 40 kg ha^{-1}) on rice cv. Swarna and PR-108 in Varanasi, Uttar Pradesh. India. They reported that plant height, tillers m^{-2} row length, dry matter production, panicle length and grains panicle $^{-1}$ were significant with increasing levels of S up to 40 kg S ha^{-1}. They also found that total N uptake, grain, straw and grain protein yields significantly improved with the increasing level S application being the maximum at 40 kg S ha^{-1} respectively.

Peng *et al*. (2002) carried out a field experiment where the average content of available S in these soil samples was 21.7 mg kg^{-1}. The soil with available S content was lower than the critical value of 16 mg kg^{-1} accounted for 57.8%. Field experiments showed that there was a different yield-increasing efficiency by applying S at the doses of 20-60 kg ha^{-1} to rice plant.

2.1.5 Effect of zinc

Kabeya and Shankar (2013) reported that rice (*Oryza sativa*) is the worlds' most important cereal and potentially an important source of zinc (Zn) for people who eat mainly rice. Zinc deficiency being a major constraint to reduce the potential yield of rice. To improve Zn delivery by rice, plant Zn uptake and internal allocation need to be better investigated. The highest effect was observed when treated with 30 kg $ZnSO_4$ ha^{-1} irrespective of zinc groups. However, high zinc groups showed better uptake ability in zinc content and overall performance in growth characteristics.

A field experiment was conducted by Dixit *et al*. (2012) to study the effect of sulphur and zinc on yield, quality and nutrient uptake by hybrid rice grown in sodic soil and that positive response of hybrid rice to zinc application was noticed significantly up to the zinc dose @ 10 kg ha^{-1}.

An experiment was carried out by Singh *et al.* (2012) at Sari, Mazandaran, Iran and reported that the maximum panicle number m^{-2} and harvest index were observed with 4 kg Zn ha^{-1} and the least of those was obtained in control treatment. The highest zinc content in grain, zinc uptake in grain and straw, and nitrogen uptake in grain were observed with 4 kg Zn ha^{-1}, as the most zinc content in straw, nitrogen, potassium, phosphorus and sulphur content in grain and straw, and nitrogen uptake in straw were observed highest with application of 4 and 2 kg Zn ha^{-1}.

Muthukumararaja and Sriramachandrasekhara (2012) reported that zinc deficiency in flooded soil is impediment to obtain higher rice yield. Zinc deficiency is corrected by application of suitable zinc fertilizer. The results revealed that rice responded significantly to graded dose of zinc. The highest grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) was noticed at 5 mg Zn kg^{-1}, which was about 100% and 86% greater than control (no zinc) respectively. The highest zinc concentration and uptake in grain and straw and DTPA-Zn at all stages was noticed at 7.5 mg Zn kg^{-1}. The agronomic, physiological and agrophysiological apparent recovery and utilization efficiencies was highest at lower level of zinc application and decreased with Zn doses.

The study was conducted by Mustafa *et al*. (2011) at agronomic research area, University of Agriculture, Faisalabad, to evaluate the effect of different methods and timing of zinc application on growth and yield of rice. Experiment was comprised of eight treatments viz., control, rice nursery root dipping in 0.5% Zn solution, $ZnSO_4$ application at the rate of 25 kg ha^{-1} as basal dose, foliar application of 0.5% Zn solution at 15, 30, 45, 60 and 75 days after transplanting. Maximum productive tillers per m^2 (249.80) were noted with basal application at the rate 25 kg ha^{-1} of $ZnSO_4$ (21% Zn) and minimum (220.28) were recorded with foliar application at 60 DAT @ 0.5% Zn solution. Maximum paddy yield (5.21 t ha^{-1}) was achieved in treatment Zn_2 (Basal application at the rate of 25 kg ha^{-1} of $ZnSO_4.7H_2O$) and minimum paddy yield (4.17 t ha^{-1}) was noted in Zn_7 (foliar application at 75 DAT @ 0.5% Zn solution).

Naik and Das (2007) reported that rice is mostly transplanted under puddled low land soil conditions in India, where zinc (Zn) deficiency is a common problem. The soil application of Zn at 1.0 kg ha^{-1} as Zn-EDTA (T_7) recorded highest grain yield of 5.42 t ha^{-1}, filled grain percentage of 90.2%, 1000-grain weight of 25.41 g and number of panicles m^{-2} of 452. The Zn content of grain and straw were also found to be maximum in the treatment T_7 i.e. 38.19 and 18.27 mg Zn kg^{-1}, respectively.

A study was carried out by Cheema *et al*. (2006) to evaluate the effect of four zinc levels on the growth and yield of coarse rice cv. IR-6 at Faisalabad, Pakistan. Four zinc levels viz., 2.5, 5.0, 7.5 and 10.kg $ZnSO_4$ ha^{-1} increased yield and yield component as compared with control. Plant height, number of tillers $hill^{-1}$, panicle bearing tillers, number of primary and secondary spikelets, panicle size, 1000 grain weight, paddy and straw yield and harvest index showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

A field experiment was conducted by Ullah *et al*. (2001) in Mymensingh, Bangladesh, to study the effect of zinc sulfate (0, 10, and 20 kg ha^{-1}) on rice cv. BR30. Plant height; tiller number; 1000-grain weight; grain and straw yields; and grain, straw, and soil Zn contents increased with zinc sulfate application. The tallest plants (75.667 cm) and the highest number of tillers (10.60 $hill^{-1}$), 1000-grain weight (28.700 g), and the concentration of Zn in straw (101.93 ppm) and grain (73.33 ppm) were obtained with 20 kg zinc sulfate ha^{-1}.

2.2 Effect of granule fertilization on rice

Rahman *et al.* (2016) carried out a field experiment to assess the comparative advantages of using USG and NPK briquette over normal urea and also predict the better performing transplanted Aus rice in the tidal ecosystem. They reported that plant height, number of effective tillers hill^{-1}, panicle length, number of grains panicle^{-1}, NUE (%), straw yield (t ha^{-1}) and grain yield (t ha^{-1}) were found highest when USG was applied with BRRI dhan48 and all the characters showed lowest value when absolute control with BRRI dhan55. Highest number of effective tillers hill^{-1} (11.15) and grain yield (3.33 t ha^{-1}) was obtained from USG and BRRI dhan48 and where lowest number of effective tillers hill^{-1} (9.21) and grain yield (2.28 t ha^{-1}) in absolute control with BRRI dhan55. The NPK briquettes showed higher agronomic efficiency than PU and USG. The USG (1.8 g) and NPK briquettes (2.4 g) could save 11.3 and 19.55 kg N ha^{-1} compared to recommended PU.

Haque and Pervin (2015) conducted an experiment to study the effect of varieties and number of guti urea hill^{-1} on the yield of T. *aman* rice. They found that, the tallest plant (136.4 cm), higher straw yield (10.99 t ha^{-1}) and higher biological yield (16.49 t ha^{-1}) were recorded in 2 guti hill^{-1} of Shakorkura while 2 guti hill^{-1} interaction with BRRI dhan51 showed the maximum effective (8.767) and total tillers hill^{-1} (9.833), maximum total grains panicle^{-1} (147.4), 1000-grain weight (32.07 g) and grain yield (6.420 t ha^{-1}). These results suggested that the variety BRRI dhan51 and 2 guti hill^{-1} individually or combined would be more effective for greater yield of T. *aman* rice.

Ferdous *et al.* (2014) conducted a field experiment to evaluate the effects of PU, USG on NUE and yield performance of rice (BRRI dhan29). Application of N as PU and USG resulted in a significant increase in yield components, grain and straw yields of BRRI dhan29. 52 kg N ha^{-1} from USG + 52 kg N ha^{-1} from PU produced the highest grain (5.82 t ha^{-1}) and straw (7.28 t ha^{-1}) yields. The lowest grain (2.78 t ha^{-1}) and straw (3.26 t ha^{-1}) yields were recorded in control plots.

Afroz (2013) conducted a field experiment to investigate the effects of PU, USG, and NPK briquettes on growth and yield of BRRI dhan28. She found that USG performed better in increasing grain yield of rice compared to PU. Debnath *et al.* (2013) carried out a field experiment to assess the comparative advantages of USG and NPK briquette over normal urea, Triple super phosphate and Muriate of Potash and also predict the better performing T. *aman* rice. The analysis revealed that different fertilizer management practices with a few exceptions significantly influenced the growth, yield and yield attributes of the T. *aman* rice. Plant height, number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, panicle length (cm), number of grains panicle^{-1}, number of sterile spikelet's panicle^{-1}, NUE (%), straw yield and grain yield were found highest when NPK briquette was applied and all the characters showed lowest value when control. Highest number of effective tillers hill^{-1} (13.00) and grain yield (6.60 t ha^{-1}) was obtained from NPK briquette and where lowest number of effective tillers hill^{-1} (5.66) and grain yield (4.48 t ha^{-1}) from USG. The NPK briquettes showed higher agronomic efficiency than PU and USG. The small size briquettes (2.4 g) could save 33 kg N ha^{-1} compared to recommend PU.

Hasanuzzaman *et al.* (2013) carried out a field experiment was to study the influence of PU and USG on the growth and yield of hybrid rice Heera1. 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.

Islam *et al.* (2013) conducted a field experiment to find out the varietal performance of *aman* rice as affected by different methods of urea application. The results showed that urea fertilizer application method significantly influenced plant height, tillering production, leaf area index, effective tillers hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panicle^{-1}, 1000-

grain weight, grain yield, straw yield, and biological yield. Application of USG N as at 7 DAT gave highest yield (7.82 t ha^{-1}) while application of 15 kg N ha^{-1} as PU 30 DAT+ 15 kg N ha^{-1} as PU at 50 DAT gave lowest yield (4.88 t ha^{-1}).

Naznin *et al.* (2013) conducted an experiment to investigate the effects of PU, USG and NPK briquette on NH_4- N concentration in field water, yield and NUE of BR22 rice under reduced water conditions. The highest grain yield (3.93 t ha^{-1}) was recorded from 104 kg N ha^{-1} as USG and the lowest value of 2.12 t ha^{-1} was obtained from control. The NUE was increased when the N was applied as USG. The overall results revealed that application of USG and NPK briquette may be practiced for obtaining better yields in addition to increasing the efficiency of N fertilizer.

Shah *et al*. (2013) conducted experiments at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, BRRI regional station Sagordi, Barisal to evaluate the NPK briquette efficiency in rice production. Experimental results revealed that deep placement of NPK briquette (2×2.4 g) 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 (1×3.4 g) 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.

Paul (2013) conducted an experiment with three USG levels and showed that leaf area index was significantly influenced by application of USG. He reported that the highest leaf area was found at 60 DAT when 1.8 g USG was applied and lowest was found at 15 DAT when 2.7 g USG was applied. Sabnam (2013) conducted a field experiment at Bangladesh Agricultural University, Mymensingh to investigate the effects of PU, USG, and NPK briquettes on yield of BR22 rice under continuous flooded condition. She reported that rice grain yield was higher from USG in comparison with Prilled Urea.

Naznin (2012) conducted an experiment at Bangladesh Agricultural University, Mymensingh during the *aman* season of 2012 to investigate the effect of PU, USG and NPK briquette on ammonium concentration in rice field water, yield and NUE of BR 22 rice under reduced water conditions. Application of PU, USG and NPK briquette showed a positive effect on yield of BR 22 rice. The highest grain yield of 3.93 t ha^{-1} was recorded from 104 kg N ha^{-1} from USG which was significantly superior to PU. This might be due to optimum release of N from deep placed fertilizers (USG) for a prolonged period.

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

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 fertilizer through briquettes (56-30-30 kg NPK ha^{-1}) as compared to the application of conventional fertilizers (100-50-50 kg NPK ha^{-1}).

Cited review revealed that recommended doses of fertilizer in different form was more effective than the conventional form on growth and yield components of rice but the information was not conclusive. Therefore, research on NPK granule fertilization is necessary to assess for better crop production.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to assess the effect of NPK briquette fertilization on the growth and yield of aromatic rice variety BRRI dhan70. The details of the materials and methods for the conduction of experiment i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatment and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period of July to November, 2017.

3.1.2 Experimental location

The present research work was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.4 meter above from sea level. Experimental location presented in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al*., 1979). Details of the meteorological data of the experimental period were presented in Appendix II.

3.1.4 Soil characteristics

The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988). Top soil was Silty Clay Loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.07 and had organic matter 1.32%. The experimental area was flat having available irrigation and drainage system and above flood level. The details have been presented in Table 1 and 2.

Table 1. Morphological characteristics of the experimental field

Morphology	Characteristics
Locality	SAU farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Shallow Red Brown Terrace Soil
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

Table 2. Initial physical and chemical characteristics of the experimental soil (0-15 cm depth)

Characteristics	Value
Mechanical fractions:	
% Sand (2.0-0.02 mm)	18.30
% Silt (0.02-0.002 mm)	45.50
% Clay (<0.002 mm)	36.20
Textural class	Silty Clay Loam
Consistency	Granular and friable when dry
pH (1: 2.5 soil- water)	6.07
Organic Matter (%)	1.32
Total N (%)	0.062
Available P (mg kg^{-1})	19.76
Exchangeable K (mol kg^{-1})	0.13
Available S (mg kg^{-1})	14.83

3.2 Experimental details

3.2.1 Planting material

In this experiment BRRI dhan70 aromatic rice were used as the test crop which was developed at the Bangladesh Rice Research Institute through hybridization and pedigree selection and released in the year 2013. It is recommended for *Aman* season. Average plant height of the variety is around 125 cm at the ripening stage. The grains are long, slender, aromatic and white in color. It requires about 130 days completing its life cycle with an average grain yield of around 4.8 t ha^{-1} (BRRI, 2016).

3.2.2 Treatment of the experiment

The experiment comprised of the following 7 treatments as-

T_0: Control i.e. no fertilizer

T_1: 100% RFD

T_2: 120% RFD

T_3: 80% RFD

T_4: 1 NPK briquette in between 4 hills

T_5: 2 NPK briquette in between 4 hills

T_6: 80% RFD + 1 NPK briquette in between 4 hills

RFD-Recommended Fertilizer Doses (120, 20, 80, 16 and 2 kg ha^{-1} of N, P, K, S and Zn, respectively)

3.2.3 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 28.50 m × 13.75 m was divided into 3 blocks. The size of the each unit plot was 3.75 m × 3.50 m. The space between two blocks and two plots were 0.75 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

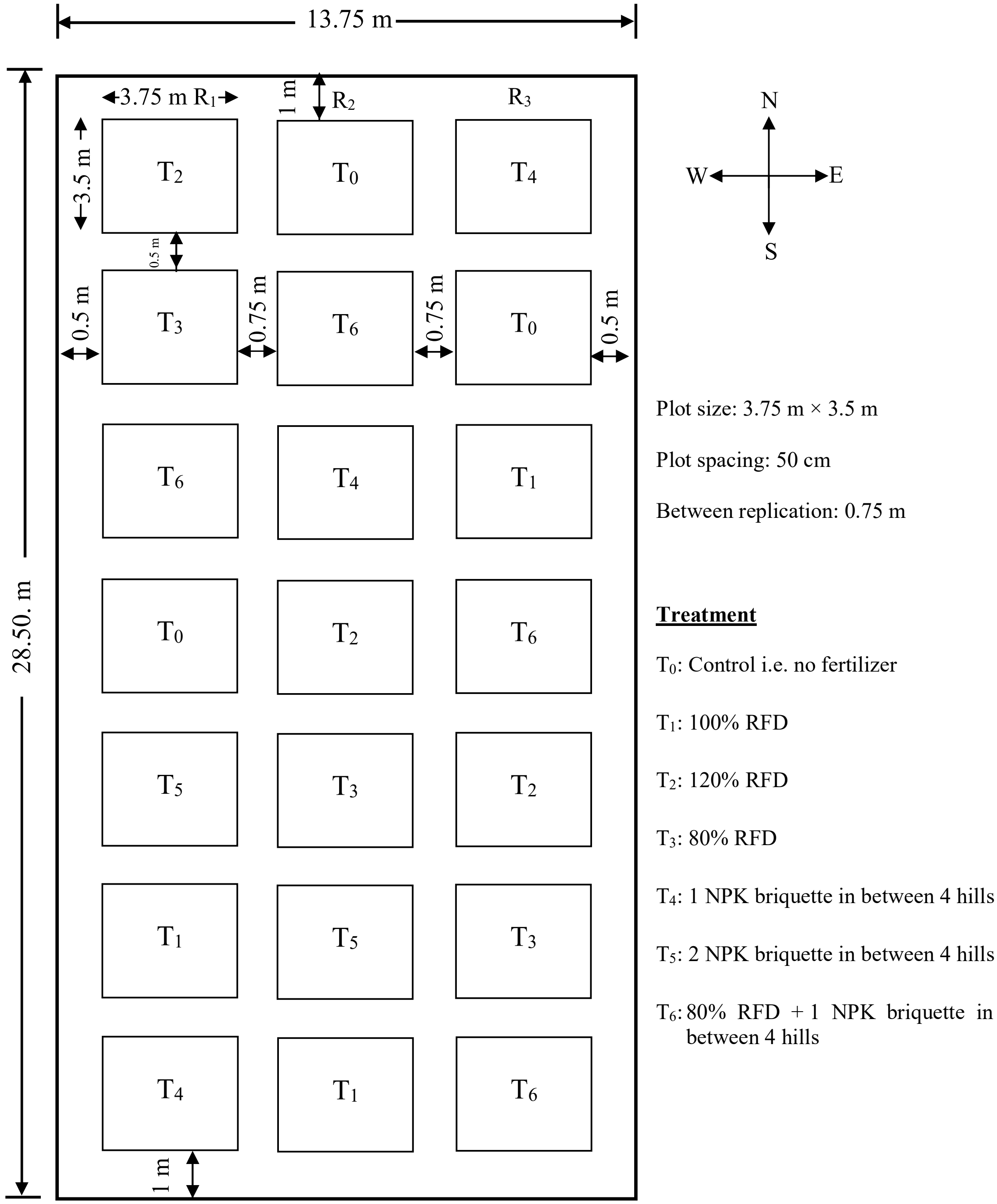

Figure 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur just 20 days ahead of the sowing of seeds in seed bed. For seedling raising clean seeds were immersed in water in a bucket for 24 hours. The imbibed seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 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 on beds on 13th July, 2017 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 plot selected for conducting the experiment was opened on 28th July 2017 with a power tiller, and left exposed to the sun for 4 days. After 04 days the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Fertilizer were applied as per treatment.

3.3.4 Fertilizers application

The fertilizers were applied as per treatment and the entire amounts of TSP, MoP, gypsum and zinc sulphate were applied during the final preparation of experimental plot. NPK briquette in between 4 hills were applied on 21st August, 2017 and 2nd and 3rd split of urea were applied 05th September, 2017 and 25th September, 2017, respectively.

3.3.5 Transplanting of seedling

Twenty five days old seedlings were carefully uprooted from the seedling nursery and transplanted on 7th August, 2017 in well puddled plot. 2/3 number of seedlings hill^{-1} was transplanted in each hill with maintaining distance plant to plant 15 cm and row to row 20 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required followed by the treatment of number of seedlings hill^{-1}.

3.3.6 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:

3.3.6.1 Irrigation and drainage

In the early stages of establishment of the seedlings irrigation was provided to maintain a constant level of standing water upto 6 cm and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 25 DAT and 45 DAT by sickles.

3.3.6.3 Insect and pest control

There was no infection of diseases in the field but leaf roller (*Chaphalocrosis medinalis*) was found in the field and used Malathion @ 1.12 L ha^{-1} at 30 DAT with using a hand sprayer.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 22th November, 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 up to moisture content 12%, then cleaned and weighed for individual plot. Yields of rice grain and straw 1 m^2 were recorded from each plot and converted to hectare yield and expressed in t ha^{-1}.

3.5 Data recording

3.5.1 Plant height

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

3.5.2 Effective tiller $hill^{-1}$

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

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

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

3.5.4 Total tiller $hill^{-1}$

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

3.5.5 Length of panicle

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

3.5.6 Filled grain $panicle^{-1}$

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 grain $panicle^{-1}$ was recorded.

3.5.7 Unfilled grain panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grain panicle^{-1} was recorded.

3.5.8 Total grain panicle^{-1}

The total numbers of grain was collected randomly from selected 10 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.5.9 Weight of 1000 seeds

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

3.5.10 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record the final grain yield plot^{-1} and finally converted to t ha^{-1}.

3.5.11 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record the final straw yield plot^{-1} and finally converted to t ha^{-1}.

3.5.12 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.

3.6 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 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. pH, organic matter, total N, available P and exchangeable K. The soil samples were analyzed by the following standard methods as follows:

3.7.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.7.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method (Page *et al.*, 1982). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage.

3.7.3 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into Micro Kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.7.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.7.5 Exchangeable potassium

Exchangeable K in post-harvest soil was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*., 1982).

3.8 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments. The mean values of all the characters were calculated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the differences among the treatment means were estimated by the Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to assess the effect of NPK briquette fertilization on the growth and yield of aromatic rice variety BRRI dhan70. Data were recorded on different yield contributing characters, yield and characteristics of post-harvest soil. The results have been presented and discussed under the following headings and sub-headings:

4.1 Yield attributes and yield of rice

4.1.1 Plant height

Plant height of aromatic rice variety BRRI Dhan70 at harvest showed statistically significant differences due to different treatments (Table 3). During harvest, the longest plant (126.06 cm) was recorded from T_6 treatment (80% RFD + 1 NPK briquette in between 4 hills) which was statistically similar (124.64 cm, respectively) to T_1 (100% RFD) treatment and followed (120.96, 120.31, 119.50 and 119.03 cm, respectively) by T_2 (120% RFD), T_3 (80% RFD), T_5 (2 NPK briquette in between 4 hills) and T_4 (1 NPK briquette in between 4 hills) treatment and they were statistically similar. The shortest plant (110.68 cm) was found from T_0 (control condition i.e. no chemical fertilizer) treatment. Plant height is a genetical character and specific variety produced more or less similar size of plant but it may differ due to prevailing different biotic and abiotic factors. Data revealed that all the treatments produced significantly tallest plant compared to the control but less than the recommended doses of fertilizer with NPK briquette produced the longest plant. Different authors previously recorded variation due to the application of granule fertilization. Islam *et al.* (2011) reported that NPK briquettes, USG and prilled urea (PU) produced longest plant than the control condition. Similar results were also recorded by Afroz (2013) and she reported that NPK briquette as granule NPK fertilizer produced the longest plant.

Table 3. Effect of NPK briquette fertilization on plant height and effective, non-effective and total tillers hill^{-1} of aromatic rice variety BRRI dhan70

Treatments	Plant height (cm)	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Total tillers hill^{-1}
T_0	110.68 c	15.40 f	2.80 a	18.20 e
T_1	124.64 a	20.53 bc	2.73 ab	23.27 b
T_2	120.96 b	20.87 b	2.33 c	23.20 b
T_3	120.31 b	19.13 cd	2.53 bc	21.67 bc
T_4	119.03 b	16.93 ef	2.33 c	19.27 e
T_5	119.50 b	17.00 ef	2.73 ab	19.73 de
T_6	126.06 a	22.80 a	2.33 c	25.13 a
$LSD_{(0.05)}$	3.777	1.562	0.227	1.559
Significance level	0.05	0.05	0.05	0.01
CV(%)	6.13	4.91	5.19	4.31

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

T_0: Control i.e. no fertilizer

T_1: 100% RFD

T_2: 120% RFD

T_3: 80% RFD

T_4: 1 NPK briquette in between 4 hills

T_5: 2 NPK briquette in between 4 hills

T_6: 80% RFD + 1 NPK briquette in between 4 hills

RFD-Recommended Fertilizer Doses (120, 20, 80, 16 and 2 kg ha^{-1} of N, P, K, S and Zn, respectively)

4.1.2 Number of effective tillers hill^{-1}

Different treatments showed statistically significant differences in terms of number of effective tillers hill^{-1} due (Table 3). Data revealed that the maximum number of effective tillers hill^{-1} (22.80) was observed from T_6 treatment which was followed (20.87 and 20.53, respectively) by T_2 and T_1 treatment and they were statistically similar, whereas the minimum number (15.40) was found from T_0 treatment which was statistically similar (16.93 and 17.00, respectively) to T_4 and T_5 treatment. Islam *et al*. (2011) that NPK briquettes, USG and prilled urea (PU) produced significantly highest effective tillers hill^{-1} than control. Afroz (2013) reported that the highest number of effective tillers hill^{-1} (13.00) was obtained from NPK briquette application.

4.1.3 Number of non-effective tillers hill^{-1}

Statistically significant variation was recorded due to different treatments in terms of number of non-effective tillers hill^{-1} (Table 3). The maximum number of non-effective tillers hill^{-1} (2.80) was recorded from T_0 treatment which was statistically similar (2.73) to T_1 and T_5 treatments and which was also followed (2.53) by T_3 treatment, while the minimum number (2.33) was observed from T_2, T_4 and T_6 tretaments. Rahman *et al.* (2016) recorded highest number of non-effective tillers due to granule fertilization and other form of fertilization than control.

4.1.4 Number of total tillers hill^{-1}

Number of total tillers hill^{-1} showed statistically significant differences due to different treatments (Table 3). The maximum number of total tillers hill^{-1} (25.13) was observed from T_6 treatment which was followed by (23.27, 23.20 and 21.67, respectively) T_1, T_2 and T_3 treatments and they were statistically similar, whereas the minimum number (18.20) was found from T_0 treatment which was statistically similar (19.27) to T_4 treatments. Islam *et al*. (2011) reported that NPK briquettes, USG and prilled urea (PU) produced significantly highest total tillers hill^{-1} than control.

4.1.5 Length of panicle

Statistically significant difference was observed in terms of length of panicle due to different treatments (Table 4). The longest panicle (26.63 cm) was recorded from T_6 treatment which was statistically similar (25.30 cm) to T_1 treatment and followed (22.30, 22.13, 21.90 and 20.30 cm, respectively) by T_2, T_3, T_5 and T_4 treatments and they were statistically similar. The shortest panicle (19.50 cm) was found from T_0 treatment. As a genetical character specific variety produced same length of panicle but it may differ due to prevailing different biotic and abiotic factors. Data revealed that all the treatments produced significantly tallest panicle compared to the control but less than the recommended doses of fertilizer with NPK briquette produced the longest panicle. Hasanuzzaman *et al.* (2013) recorded the longest panicle from the application of USG.

4.1.6 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} varied significantly due to different treatments (Table 4). The maximum number of filled grains panicle^{-1} (120.60) was observed from T_6 treatment which was statistically similar (115.60) to T_1 treatment and followed (110.67) by T_2 treatment, while the minimum number (101.60) was found from T_0 treatment which was statistically similar (102.60, 105.20) to T_4 and T_5 treatments. Islam *et al*. (2011) that NPK briquettes, USG and prilled urea (PU) produced significantly highest number of filled grains panicle^{-1}.

4.1.7 Number of unfilled grains panicle^{-1}

Statistically significant variation was recorded in terms of number of unfilled grains panicle^{-1} due to different treatments (Table 4). The maximum number of unfilled grains panicle^{-1} (9.47) was recorded from T_0 treatment which was statistically similar (9.00) to T_3 treatment and followed (8.00, 7.87 and 7.73, respectively) by T_1, T_6, T_5 and T_2 treatments and they were statistically similar, while the minimum number (6.67) was observed from T_4 treatment. Afroz (2013) reported that the lowest number of unfilled grains panicle^{-1} was obtained from NPK briquette and the lowest from USG.

Table 4. Effect of NPK briquette fertilization on length of panicle, number of filled, unfilled and total grains panicle^{-1} of aromatic rice variety BRRI dhan70

Treatments	Length of panicle (cm)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Total grains panicle^{-1}
T_0	19.50 c	101.60 d	9.47 a	111.07 d
T_1	25.30 a	115.60 ab	8.00 b	123.60 ab
T_2	22.30 b	110.67 bc	7.53 b	118.20 bc
T_3	22.13 bc	108.87 c	9.00 a	117.33 bc
T_4	20.30 bc	102.60 d	6.67 c	109.27 d
T_5	21.90 bc	105.20 cd	7.73 b	112.93 cd
T_6	26.63 a	120.60 a	7.87 b	128.47 a
$LSD_{(0.05)}$	2.407	5.610	0.500	5.731
Significance level	0.05	0.05	0.01	0.05
CV(%)	6.08	4.11	5.65	6.82

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

T_0: Control i.e. no fertilizer

T_1: 100% RFD

T_2: 120% RFD

T_3: 80% RFD

T_4: 1 NPK briquette in between 4 hills

T_5: 2 NPK briquette in between 4 hills

T_6: 80% RFD + 1 NPK briquette in between 4 hills

RFD-Recommended Fertilizer Doses (120, 20, 80, 16 and 2 kg ha^{-1} of N, P, K, S and Zn, respectively)

4.1.8 Number of total grains panicle^{-1}

Different treatments showed statistically significant differences in terms of number of total grains panicle^{-1} (Table 4). The maximum number of total grains panicle^{-1} (128.47) was found from T_6 treatment which was statistically similar (123.60) to T_1 treatment and followed (118.33 and 117.33, respectively) by T_2 and T_3 treatments and they were statistically similar, while the minimum number (109.27) was recorded from T_4 treatment (Table 4). Naznin *et al.* (2013) stated that that application of USG and NPK briquette may be practiced for obtaining highest total grains panicle^{-1}.

4.1.9 Weight of 1000 grains

Weight of 1000 grains showed statistically non-significant differences due to different treatments under the present trial (Table 5). The highest weight of 1000 grains (22.40 g) was recorded from T_6 treatment, while the lowest weight (21.81 g) was found from T_0 treatment. Afroz (2013) reported that the highest weight of 1000 grains was obtained from NPK briquette and the lowest from USG.

4.1.10 Grain yield

Statistically significant variation was observed in terms of grain yield due to different treatments (Table 5). The highest grain yield (4.72 t ha^{-1}) was recorded from T_6 treatment, which was followed (4.39 t ha^{-1}) by T_2, while the lowest grain yield (2.04 t ha^{-1}) was found from T_0 treatment which was followed (2.89 t ha^{-1}) by T_4 treatment. Application of USG and NPK briquette may be practiced for obtaining better yields which was earlier stated by Naznin *et al.* (2013). Afroz (2013) recorded the highest grain yield (6.60 t ha^{-1}) from NPK briquette and the lowest grain yield (4.48 t ha^{-1}) from USG. But in another experiment Rahman *et al.* (2016) recorded highest grain yield (3.33 t ha^{-1}) from USG and lowest grain yield (2.28 t ha^{-1}) in absolute control.

Table 5. Effect of NPK briquette fertilization on weight of 1000 grains, grain, straw and biological yield of aromatic rice variety BRRI dhan70

Treatments	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
T_0	21.81	2.04 e	3.73 e	5.77 e
T_1	22.33	3.46 c	4.94 ab	8.40 c
T_2	22.29	4.39 b	5.24 ab	9.63 b
T_3	22.15	3.50 c	4.63 bc	8.14 cd
T_4	22.22	2.89 d	4.48 d	7.37 d
T_5	22.25	3.50 c	3.94 d	7.44 d
T_6	22.40	4.72 a	5.40 a	10.12 a
$LSD_{(0.05)}$	--	0.293	0.634	0.704
Significance level	NS	0.05	0.01	0.01
CV(%)	6.06	5.91	7.05	4.28

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

T_0: Control i.e. no fertilizer

T_1: 100% RFD

T_2: 120% RFD

T_3: 80% RFD

T_4: 1 NPK briquette in between 4 hills

T_5: 2 NPK briquette in between 4 hills

T_6: 80% RFD + 1 NPK briquette in between 4 hills

RFD-Recommended Fertilizer Doses (120, 20, 80, 16 and 2 kg ha^{-1} of N, P, K, S and Zn, respectively)

4.1.11 Straw yield

Different treatments showed statistically significant differences in terms of straw yield (Table 5). The highest straw yield (5.40 t ha^{-1}) was found from T_6 treatment, which was statistically similar (5.24 and 4.94 t ha^{-1}, respectively) to T_2 and T_1 treatments and followed (4.63 t ha^{-1}) by T_3 treatment, whereas the lowest straw yield (3.73 t ha^{-1}) from T_0 treatment (Table 5). Afroz (2013) reported that the highest straw yield was obtained from NPK briquette.

4.1.12 Biological yield

Statistically significant variation was recorded in terms of biological yield due to different treatments under this trial (Table 5). The highest biological yield (10.12 t ha^{-1}) was found from T_6 which was followed (9.63) by T_2 treatment, while the lowest biological yield (5.77 t ha^{-1}) from T_0 treatment (Table 5). Similar results also reported by Naznin *et al.* (2013) earlier and they reported that application of USG and NPK briquette may be practiced for obtaining better biological yields.

4.2 Soil pH, organic matter, total N, available P and exchangeable K in post-harvest soil

4.2.1 Soil pH

Soil pH in post-harvest showed statistically non-significant differences due to different treatments (Figure 2). The maximum soil pH (6.12) was found from T_6 treatment and the minimum soil pH (5.97) was from T_0 treatment.

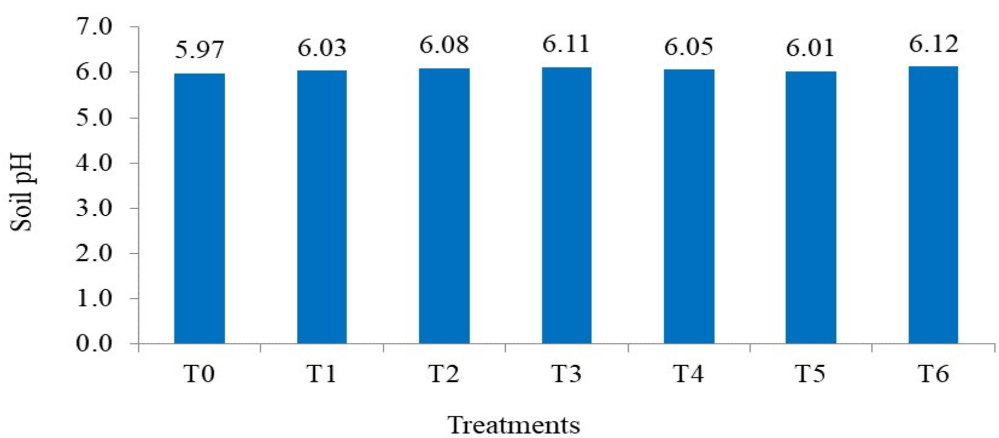

Figure 2. Effect of NPK briquette on pH of post harvest soil

4.2.2 Organic matter

Statistically non-significant variation was recorded in terms of organic matter content in post-harvest soil due different treatments (Figure 3). The highest organic matter (1.32%) was observed from T_6 treatment and the lowest organic matte (1.22%) was found from T_0 treatment.

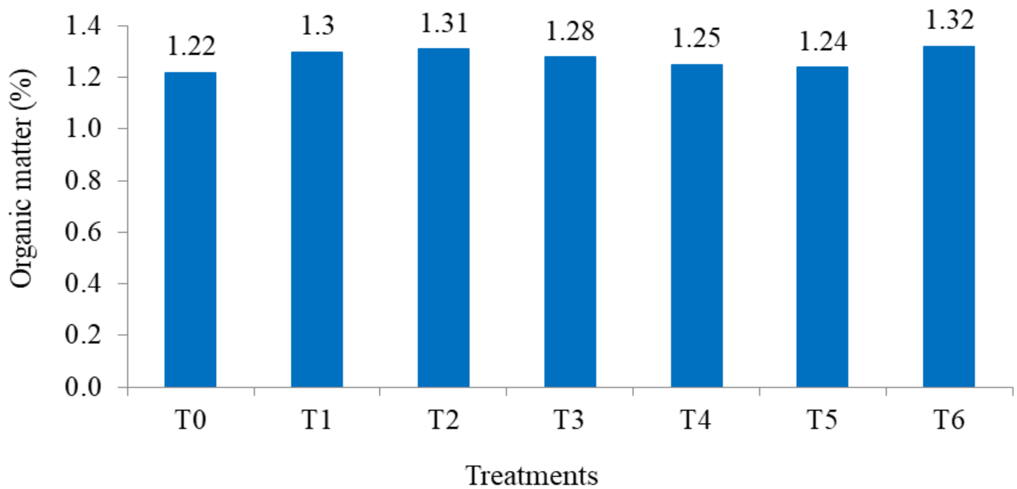

Figure 3. Effect of NPK briquette on organic organic matter content of post harvest soil

4.2.3 Total N

Total N in post-harvest soil showed statistically significant differences due to the effect of different treatments (Table 6). The highest total N (0.067%) was found from T_6 treatment which was statistically similar (0.060% and 0.059%, respectively) to T_2 and T_1 treatment and followed (0.041%, 0.040% and 0.039%, respectively) by T_3, T_5 and T_4 treatment, while the lowest soil total N (0.021%) was observed from T_0 treatment.

4.2.4 Available P

Available P in post-harvest soil showed statistically significant differences due to the effect of different treatments (Table 6). The highest available P (39.32 ppm) was observed from T_6 treatment which was followed (33.14 ppm, 31.73 ppm and 27.87 ppm, respectively) by T_1, T_2 and T_3 treatments and they were statistically similar, whereas the lowest available P (14.40 ppm) was found from T_0 treatment.

Table 6. Effect of NPK briquette fertilization on soil pH, organic matter and NPK content of post-harvest soil of aromatic rice variety BRRI dhan70

Treatments	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq/100 g soil)
T_0	5.97	1.22	0.021 c	14.40 d	0.123 f
T_1	6.03	1.30	0.059 a	33.14 b	0.164 a-c
T_2	6.08	1.31	0.060 a	31.73 bc	0.151 b-d
T_3	6.11	1.28	0.041 b	27.87 bc	0.144 de
T_4	6.05	1.25	0.039 b	15.03 d	0.128 ef
T_5	6.01	1.24	0.040 b	26.60 c	0.135 d-f
T_6	6.12	1.32	0.067 a	39.32 a	0.177 a
$LSD_{(0.05)}$	--	--	0.017	5.159	0.017
Significance level	NS	NS	0.01	0.01	0.05
CV(%)	5.73	8.53	15.56	11.17	6.45

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

T_0: Control i.e. no fertilizer

T_1: 100% RFD

T_2: 120% RFD

T_3: 80% RFD

T_4: 1 NPK briquette in between 4 hills

T_5: 2 NPK briquette in between 4 hills

T_6: 80% RFD + 1 NPK briquette in between 4 hills

RFD-Recommended Fertilizer Doses (120, 20, 80, 16 and 2 kg ha^{-1} of N, P, K, S and Zn, respectively)

4.2.5 Exchangeable K

Statistically significant difference was recorded in terms of exchangeable K in post-harvest soil due to different treatments (Table 6). The highest exchangeable K (0.177 meq/100 g soil) was observed from T_6 treatment, which was statistically similar (0.164 meq/100 g soil) to T_1 and followed (0.151 meq/100 g soil) by T_2 treatment, while the lowest exchangeable K (0.123 meq/100 g soil) was recorded from T_0 treatment.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period of July to November, 2017 in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to assess the effect of NPK briquette fertilization on the growth and yield of aromatic rice variety BRRI dhan70. The experiment comprised of the following 7 treatments as- T_0: Control i.e. no fertilizer; T_1: 100% RFD; T_2: 120% RFD; T_3: 80% RFD; T_4: 1 NPK briquette in between 4 hills and T_5: 2 NPK briquette in between 4 hills and T_6: 80% RFD + 1 NPK briquette in between 4 hills. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different yield contributing characters, yield and characteristics of post-harvest soil and statistically significant variation was recorded for different treatment.

During harvest, the longest plant (126.06 cm) was recorded from T_6 treatment, while the shortest plant (110.68 cm) was found from T_0. The maximum number of effective tillers hill^{-1} (22.80) was observed from T_6 treatment, whereas the minimum number (15.40) was found from T_0 treatment. The maximum number of non-effective tillers hill^{-1} (2.80) was recorded from T_0 treatment, while the minimum number (2.33) was observed from T_2, T_4 and T_6 tretament. The maximum number of total tillers hill^{-1} (25.13) was observed from T_6 treatment, whereas the minimum number (18.20) was found from T_0 treatment. The longest panicle (26.63 cm) was recorded from T_6 treatment, while the shortest panicle (19.50 cm) was found from T_0 treatment. The maximum number of filled grains panicle^{-1} (120.60) was observed from T_6 treatment, while the minimum number (101.60) was found from T_0 treatment. The maximum number of unfilled grains panicle^{-1} (9.47) was recorded from T_3 treatment, while the minimum number (6.67) was observed from T_4 treatment. The maximum number of total grains panicle^{-1} (128.47) was found from T_6 treatment, while the minimum number (109.27) was recorded from T_4 treatment. The highest weight of 1000 grains

(22.40 g) was recorded from T_6 treatment, while the lowest weight (21.81 g) was observed from T_0 treatment. The highest grain yield (4.72 t ha^{-1}) was recorded from T_6 treatment, while the lowest grain yield (2.04 t ha^{-1}) was found from T_0 treatment. The highest straw yield (5.40 t ha^{-1}) was found from T_6 treatment, whereas the lowest straw yield (3.73 t ha^{-1}) was recorded from T_0 treatment. The highest biological yield (10.12 t ha^{-1}) was found from T_6 treatment, while the lowest biological yield (5.77 t ha^{-1}) was recorded from T_0 treatment.

The highest soil pH (6.12) was found from T_6 treatment and the lowest soil pH (5.97) was observed from T_0 treatment. The highest organic matter (1.32%) was recorded from T_6 treatment and the lowest organic matte (1.22%) was found from T_0 treatment. The highest total N (0.067%) was found from T_6 treatment, while the lowest soil total N (0.021%) was observed from T_0 treatment. The highest available P (39.32 ppm) was observed from T_6 treatment, whereas the lowest available P (14.40 ppm) was found from T_0 treatment. The highest exchangeable K (0.177 meq/100 g soil) was observed from T_6 treatment, while the lowest exchangeable K (0.123 meq/100 g soil) was recorded from T_0 treatment.

It was observed that applications of T_6 treatment (80% RFD + 1 NPK briquette in between 4 hills) was the superior among the other treatments in consideration of yield contributing characters and yield of aromatic rice variety BRRI dhan70 followed by T_1 treatment (100% RFD).

Considering the results of the present experiment, further studies in the following areas may be suggested:

1. For regional adaptability such study is needed to be repeated/replicated in different agro-ecological zones (AEZ) of Bangladesh.
2. Other biotic and abiotic factors may be used for further study, and
3. Different combination of organic manures and chemical fertilizers may be used for further study.

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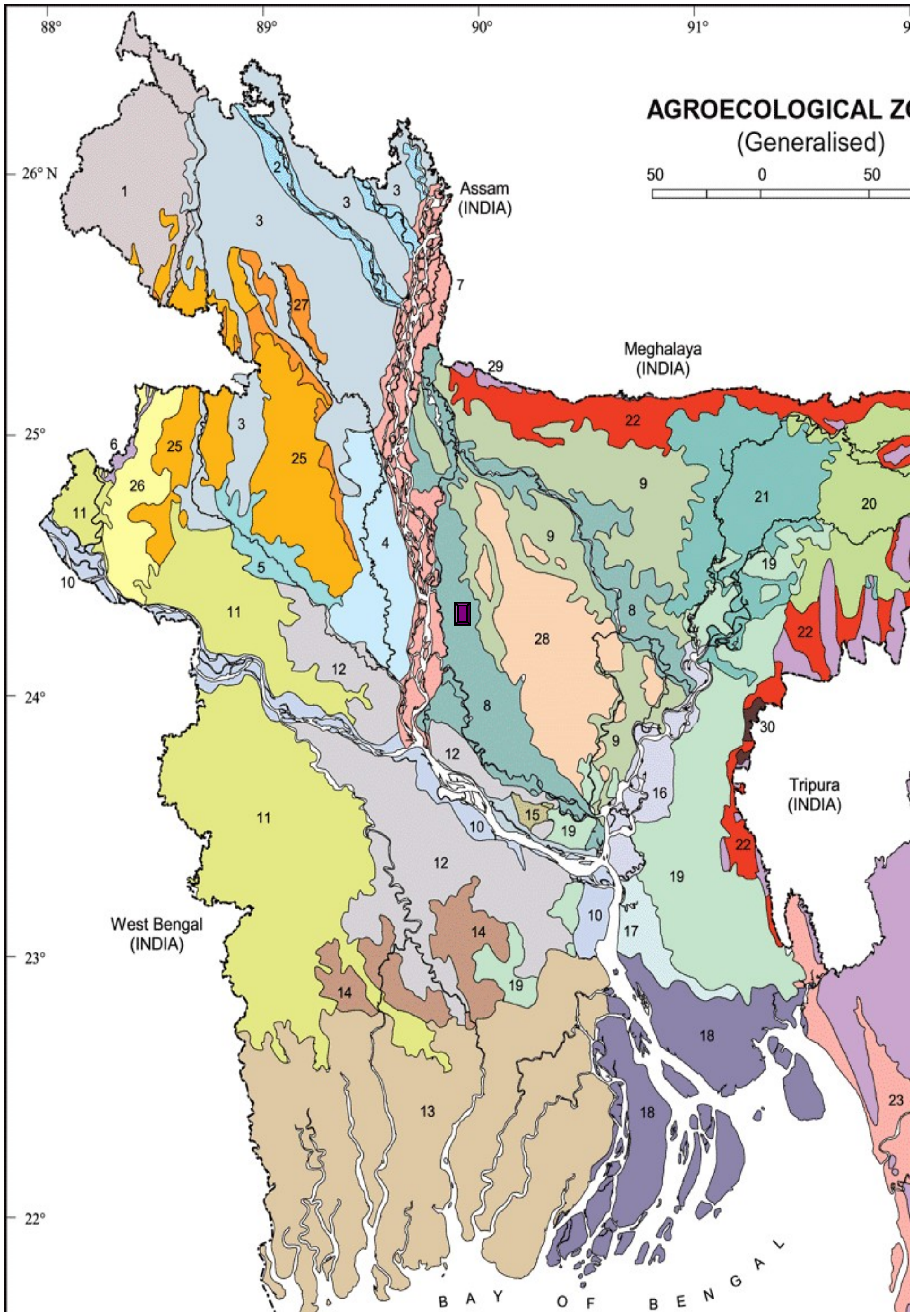
Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from July to November 2017

Month (2017)	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
July	36.8	24.9	85	573	5.5
August	35.2	23.3	87	303	6.2
September	33.7	22.6	82	234	6.8
October	26.6	19.5	79	34	6.5
November	25.1	16.2	77	00	6.7

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1207