COMPARATIVE EFFECT OF NPK BRIQUETTES AND VERMICOMPOST ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF AROMATIC RICE

T. M. ASHADUL HOSSAIN

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

DECEMBER, 2019

COMPARATIVE EFFECT OF NPK BRIQUETTES AND VERMICOMPOST ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF AROMATIC RICE

BY

T. M. ASHADUL HOSSAIN

REGISTRATION NO. 13-05627

A Thesis Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka-1207
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
SOIL SCIENCE

SEMESTER: JULY-DECEMBER, 2019

Approved By

....

A.T.M. Shamsuddoha
Professor
Department of Soil Science
Supervisor

....

Alok Kumar Paul, Ph.D.
Professor
Department of Soil Science
Co-Supervisor

....

Alok Kumar Paul, Ph.D.
Professor
Department of Soil Science
Chairman

Department of Soil Science

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar. Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"COMPARATIVE EFFECT OF NPK BRIQRETTES AND VERMICOMPOST ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF AROMATIC RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE IN SOIL SCIENCE** in **SOIL SCIENCE,** embodies the result of a piece of bona fide research work carried out by **T. M. ASHADUL HOSSAIN**, Registration No. **13-05627** under my supervision and guidance. No part of the 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:
Place: Dhaka, Bangladesh

....

A.T.M. Shamsuddoha
Professor
Department of Soil Science
Supervisor

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work. The author feels proud to express his deep sense of gratitude, sincere appreciation and immense indebtedness to his supervisor **Prof. A.T.M. Shamsuddoha**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without his intense co-operation this work would not have been possible.

The author feels proud to express his deepest respect, sincere appreciation and immense indebtedness to his co-supervisor **Prof. Dr. Alok Kumar Paul,** Department of Soil Science, SAU, Dhaka, for his scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.

The author expresses his sincere respect to **Prof. Dr. Md. Saikat Chowudhury,** Chairman, **Prof. Dr. Md. Asaduzzaman Khan, Prof. Dr. Mohammead Issak, Prof. Mst. Afrose Jahan** and **Prof. Dr. Md. Mohammed Mosharraf Hossain,** Department of Soil Science, SAU, Dhaka, for their valuable suggestions and cooperation during the study period .

The author is really indebted to his beloved friends Anika, Puja and Moon for their great support, help and encouragement and also special thanks to all other friends for their support and encouragement to complete this study. The author expresses his sincere appreciation to his father and beloved mother, sister, brother, for their moral support, encouragement and love with cordial understanding.

The Author

TABLE OF CONTENTS

Content contd.

Content contd.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

N	:	Nitrogen
P	:	Phosphorus
K	:	Potassiun
DAT	:	Days after transplanting
ANOVA	:	Analysis of variance
LSD	:	Least significant difference
df	:	Degrees of Freedom
C.V.%	;	Percentage of Coefficient of Variation
t	:	Ton
h	:	Hectare
pH	:	Potential hydrogen
ppm	:	Parts per million
RCBD	:	Randomized completely blocked design
S	:	Sulfur
CEC	:	Cation exchange capacity
meq	:	Milliequivalents
Kg	:	Kilogram

COMPARATIVE EFFECT OF NPK BRIQUETTES AND VERMICOMPOST ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF AROMATIC RICE

BY

T. M. ASHADUL HOSSAIN

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka from November 2018 to May 2019. The experiment consisted single factor: seven fertilizer management practice with NPK briquettes and vermicompost viz. T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Different fertilizer management practices influenced significantly on all of the parameters. Among the fertilizer management practices T_4 (75% NPK as NPK briquettes + 25% NPK from vermicompost) performed best in case of all of the vegetative (Plant height,number of tillers, number of effective and ineffective tillers and panicle length) and reproductive characteristics (days to panicle initiation, no of grain per panicle, no of filled and unfilled grain per panicle and1000 grain weight) and lowest result was observed from T_1. Maximum grain yield as well as straw yield was obtained from T_4 (6.7 t ha^{-1} and 7.1 t ha^{-1}). Harvest Index was the maximum for treatment T4 (48.9).

Dedicate to my

Beloved Parents

INTRODUCTION

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is an important food crop of the world. It is the staple food in South-East-Asia and at present more than half of the population depends on this crop (Manzoor *et al.*, 2006). Rice is also one of the most important cereals of Bangladesh and occupies first position as staple food. The demand for rice continues to increase owing to continued growth of population. It is predicted that a 50% to 60% increase in rice production will be required to meet demand for population growth by 2025 (Dobermann *et al*., 1998). Rice varieties are classified as aromatic and non-aromatic varieties based on aroma. Aromatic rice of all shapes and sizes available in the country represent the greater genetic diversity witnessed in the various agro climatic regions. Aromatic rice constitutes a small but special group of rice which are considered best in quality. Short, medium and long grained aromatic varieties are available. Aroma in scented rice depends on the levels of 2-acetyl-1-pyrroline content and it varies with genetic and environmental conditions (Nadaf *et al*., 2006). Nitrogen is the most important and key nutrient for rice production all over the world for its huge requirements and instability in soil. It is the most limiting element for increasing rice productivity in the tropical countries like Bangladesh. By conventional fertilizer application, one of the major problem is leaching loss of nutrients especially nitrogen. The low use efficiency of N is because of various reasons such as volatilization, denitrification, surface runoff, leaching losses and ammonium fixation in soil, for phosphorus fixation with Fe and Al in acid soil and with Ca, Mg in alkaline soil. More or less similar situation exists in case of potassium. There it would be better if all the three major plant nutrients are used in the briquette form (Kokare *et al*., 2015 and Rahman *et al*., 2016).

The NPK briquette is a mixture of urea, TSP and MoP which helps to reduce the loss of nutrients in flooded condition. So, it is very much effective for tidal flooded ecosystem. Fertilizer briquettes are hammered into the ground reduce runoff, fxation, leaching, and volatilization loss (Bautista *et al*., 2001). In

Bangladesh, yield of rice was increased by 15-25% while expenditure on commercial fertilizer was decreased by 24-32% when fertilizer briquettes were used as the source of plant nutrients. Deep placement of fertilizer briquettes is environment friendly and economically beneficial (IFPRI., 2004).

Organic agriculture is one among the broad spectrum of production methods that are supportive of the environment. The demand for organic food is gradually increasing both in developed and developing countries with an annual growth rate of 20–25 per cent (Ramesh *et al*., 2005). Compared to conventional compost, vermicompost contains large amounts of total nutrients with larger percentage of available forms. Valuable is the high number of microorganisms and also considerable level of growth regulators such as auxins, gibberellins, cytokinins. Vermicompost application accelerates the ripening process of the crop of 1–2 weeks before with improving the quality parameters of cultivated plants (Kovacik, 2014). It is eco-friendly, non-toxic, consumes low energy input for composting and is a recycled biological product (Lourduraj and Yadav, 2005). They have a high and diverse microbial and enzymatic activity, fine particulate structure, good moisture-holding capacity, and contain nutrients such as N, P, K, Ca and Mg in forms readily taken up by plants (Khalil ei al 2011; Arancon and Edwards, 2009). Vermicompost is slow releasing organic fertilizer and nutrients are available for longer period of time. Vermicompost also improves soil structure, texture, increases aeraetion, and improves water holding capacity. Hidlago *et al*., (2006) reported that the incorporation of vermicompost increased plant growth, leaf growth and root length. There is a good evidence that vermicompost promotes growth of plants and it has been found to have a favourable influence on all yield parameters of crops like, wheat, paddy, and sugarcane (Ismail., 1997; Ansari., 2007). The suitability of vermicompost amended soil for sustaining plant growth and biological activity is a function of physical properties and the chemical properties which depend on soil organic matter. Soil plays a key role in completing the cycling of major demands required by biological systems decomposing organic wastes and detoxifying certain hazardous compounds.

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. Hence the objectives are-

- To study the efficacy of NPK briquettes and vermicompost on the yield of aromatic rice, BRRI dhan 50
- To find out the suitable doses of NPK briquettes and vermicompost for maximum yield of aromatic rice.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1 Effect of Nitrogen on crop production

Of the 16 essential nutrient elements nitrogen is the major and primary elements for the growth and development and better yield of crops. Plants response best to nitrogen compared to other nutrient elements. Urea has been found to be very effective nitrogenous fertilizers. Nitrogen is play pivotal role at yield and yield attributes of rice.

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 TalataMafara.

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%.

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.

Bayan and Kandasamy (2002) noticed that the application of recommended doses of nitrogen in four splits at 10 days after sowing active tillering, panicle initiation and at heading stages recorded significantly lower dry weight of weeds and increased crop growth viz. effective tillers m^{-2}.

Duhan and Singh (2002) conducted a field experiment and 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.

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}).

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

Angayarkanni and Ravichandran (2001) conducted a field experiment in Tamil Nadu, India from July to October to determine the best split application of 150 kg N ha^{-1} for rice cv. IR20. Data from the experiment revealed that 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).

Shrirame *et al.* (2000) conducted an experiment during the kharif 1996 in Nagpur, Maharastra, India on rice cv. TNRH-10, TNRH-13 and TNRH-18 were grown at 1, 2, and 3 seedlings $hill^{-1}$ one seedling $hill^{-1}$ showed significantly higher harvest index.

Pully *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.

Geethdevi *et al*. (2000) found that 120 kg N ha^{-1} in the form of urea, 50% nitrogen was applied in four splits resulted in higher number of tillers, filled grains $panicle^{-1}$ and higher grain weight $hill^{-1}$.

2.2 Effect of Phosphorus on crop production

Tang *et al.* (2011) conducted a field experiment on winter wheat (*Triticumaestivum* 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 (EH1 and EH2) 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, P8 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 super phosphate 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, FeS2 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.

2.3 Effect of Potassium on crop production

Maryam and Ebrahim (2014) conducted this experiment to investigate the effect of nitrogen and potassium fertilizers on yield and yield components of a rice cultivar "Hashemi" as factorial laid out randomized complete block design with three replications at eastern Guilan (Amlash) during farming season 2013. The results of ANOVA revealed that the effect of potassium on height and the number of tiller was quite significant and it had significant effect on the number of filled grain. The interaction of nitrogen and potassium on height and the number of tiller was quite significant. Means comparison of data based on Duncan test for nitrogen showed that the fertilizer level of 90 kg ha^{-1} possessed the highest yield (5714 kg ha^{-1}). The highest number of tiller obtained at the fertilizer level of 90 kg ha^{-1} nitrogen with 526.7 tillers per m^{-2} and 150 kg ha^{-1} potassium with 438.8 tillers per m^{-2} . The highest number of tiller obtained when 90 kg ha^{-1} nitrogen with 150 kg ha^{-1} potassium and 90 kg ha-1 with 75 kg ha-1 potassium were applied to gain 578.3 and 546.7 tillers per m^{-2} , respectively.

Rajeev Kumar *et al.* (2013) reprted that the interaction effect of N and K was significant for number of grains per panicle, hollow grain percentage, biological yield and harvest index. Potassium application as top-dressing together with nitrogen increased potassium content of plant, grain number in panicle and straw yield f rice.

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.

Potassium is the most abundant nutrient in plants including rice plant. This is especially true for improved cultivars that uptake K considerably up to four-fold higher than native cultivars (Dobbermann *et al*. 1998; Bahmanyar and Mashaee 2010).

Li *et al*. (2009) observed that the number of tillers m^{-2}, 1000-grain weight, paddy and straw yield significantly increased with the application K with other fertilizer combinedapplication of K and N had a remarkable positive reciprocal effect on crops, and was an important approach in improving K use efficiency.

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.

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 KRH_2 performed superior with different levels of K.

Qiangsheng *et al.* (2004) reported that K uptake by rice population is maximized in the growth season of elongation stage to heading stage.

In fact continuous application of K improves all soil properties and perhaps the use of higher rates of nitrogen, application of 135kg potassium along with nitrogen has become very necessary due to intensified agriculture with high-yielding varieties (Meena *et al.* 2002).

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}.

Ranjha *et al.* (2001) conducted a pot study to see the relative effect of SOP and MOP on rice growth in sandy clay loam soil used @ 10 kg pot^{-1}. Potassium was applied @ 0, 100, 200, 300, 400 and 500 mg kg^{-1} soil each from MOP and SOP along with basal dose of N + P @ 150 and 100 kg ha^{-1}. Plant height, number of tillers pot^{-1}, paddy yield, 1000-grain weight and straw yield remained unaffected by both the sources of potassium. Nitrogen and potassium contents of rice paddy and straw were unaffected by all the treatments. However, significant increase in P contents of rice straw was noted where SOP was applied. Sulfur contents in both grain and straw increased significantly with increasing SOP rates while Cl- contents increased with increasing MOP rates. There was gradual decrease in Cl- concentration at panicle emergence, straw and paddy as compared to first sampling (35 days after transplanting)

The crop of rice is generally fertilized by farmers either with nitrogen or with nitrogen and phosphorus only, though potassium is equally important as it stabilizes yield. Potassium plays an important role in ensuring efficient utilization of nitrogen (Singh and Singh 2000).

Ahmad (1996) stated that plant growth parameters remained unaffected by K fertilization. Both the sources (i.e. MOP and SOP) failed to increase growth parameters over control and there was no ill effect of Cl- on wheat plants. Keeping all this in view, this study was planned to evaluate the effect of K sources on rice growth and uptake of nutrients.

2.4 Literature about NPK Briquettes

Roy (2019) Reported that A field experiment was conducted in kharif 2017 at the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G). The experiment was comprising of total 11 treatments; out of which, four treatments involving application of urea briquettes. The influence of the different levels and sources of Non root growth and nitrogen losses was studied under different treatments. The results revealed that Nitrogen losses in irrigated rice were significantly influenced by the treatments. The concentration of nitrates and ammonia found in leachates in treatments involving urea+organics briquettes were found significantly lower compared to rest treatments. There was a progressive increase in root dry weight and volume with the advancement of crop growth stage. The effect of different nitrogen levels and sources was found statistically significant on root growth. The highest value of root volume and dry weight were found in in treatments involving urea+FYM briquettes application. The addition of organics in urea briquettes and deep placement of briquettes exhibited better root development and lower nitrogen losses which might be attributed to slow release of nitrogen and thus reducing the losses and thereby higher nutrients uptake and ultimately higher root biomass.

Roy *et al*. (2018) reported that, a field experiment was conducted to study the impact of use of urea briquettes in combination with organics in irrigated rice cultivation system with eleven treatments each replicated four times. The experiment comprised of four treatments involving application of urea briquettes. The results revealed that the addition of organics in urea briquettes and deep placement of briquettes exhibited higher nitrogen, phosphorus and potassium use efficiency which might be attributed to slow release of nitrogen, thus reducing the losses and thereby higher nutrients uptake and ultimately higher yield. Nitrogen losses in irrigated rice were significantly influenced by the treatments. The concentration of nitrates and ammonia found in leachates in treatments involving urea+organics briquettes were found significantly lower compared to rest treatments. Application of urea briquettes significantly influenced the available N,P,K in soil at harvest. Overall, urea+FYM briquette application among different sources of fertilizer nitrogen was found most suitable for irrigated rice cultivation system and it also showed higher nitrogen use efficiency as compared to recommended dose of fertilizers.

Tapkeer, (2017) conducted a field experiment to study the “Effect of different fertilizer briquettes on yield, nutrient uptake and soil fertility status of Dolichos bean (*Dolichos lablab* L.) In lateritic soils of Konkan”. The study was formulated to reduce the fertilizer use by using briquette form. Amongst all fertilizer briquettes, UB-10:26:26 briquettes found significant in term of growth attributing characters and yield of Dolichos bean. It was observed that the application of one UB-10:26:26 briquette in between two plants at sowing was found significant in respect of yield and recorded higher plant height and number of pods per plants as well as higher total N, P and K uptake. The available nutrient status such as organic carbon, (N, P and K) in soil after harvest was found to be improved due to application of UB10:26:26 briquettes one in between two plants as compared to other treatments. In general, it is concluded that the application of UB-10:26:26 briquettes @ one briquette in between two plants was found promising in enhancing the green pod yield of Konkan bhushan variety in lateritic soils of Konkan. 50 per cent recommended dose of NPK fertilizer was reducing by the application of nutrients in the form of UB-10:26:26 briquettes

Supriyadi *et al.* (2017) conducted a study to evaluate the effectiveness of NPK compound fertilizer (22% N:12% P_2O_5:12% K_2O) in the form of granular and briquettes to growth, productivity, and sugar content. The results showed that treatments 1,000 kg/ha NPK briquettes, 300 kg/ha US, 800 kg/ha NPK briquette, and 300 kg/ha US resulted in higher growth, productivity, and sugar production compared to farmer's application. The treatment 800 kg/ha NPK briquette of is the most efficient in increasing productivity (22.29 ton/ha), sugar production (2.03 ton/ha), and net profit (Rp11,013,120/ha).

Rahman *et al*. (2016) conducted a field experiment at the field laboratory of Department of Agronomy, Patuakhali Science and Technology University, to assess the comparative advantages of using Urea Super Granule (USG) and NPK briquette over normal urea and also predict the better performing transplanted Aus rice in the tidal ecosystem. The effect of different levels of fertilizer was studied on growth, yield and yield attributing character of transplanted Aus rice. Analysis revealed that different fertilizer management practices with a few exceptions significantly influenced the growth, yield and yield attributes of the transplanted Aus rice varieties. Plant height, number of effective tillers per hill, panicle length (cm), number of grains panicle^{-1}, nitrogen use efficiency (%), straw yield (t ha^{-1}) and grain yield (t ha^{-1}) were found highest when USG was applied with BRRIdhan48 and all the characters showed lowest value when absolute control with BRRIdhan55. Highest number of effective tillers per hill (11.15) and grain yield (3.33 t ha^{-1}) was obtained from USG and BRRIdhan48 and where lowest number of effective tillers per hill (9.21) and grain yield (2.28 t ha^{-1}) in absolute control with BRRIdhan55. The NPK briquettes showed higher agronomic efficiency than

Prilled Urea (PU) and Urea Super Granule (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. There was no residual effect of USG on soil chemical properties. The USG with BRRIdhan48 were found beneficial to the farmers in tidal ecosystem.

Akter *et al.* (2015) conducted an experiment to evaluate the performance of deep placement of urea and NPK briquettes compared to broadcast application of prilled urea for bitter gourd production during the Kharif-1 season of 2013. The experiments were conducted in two locations in Jessore district, Chowgacha and Jessoresadar. Seven treatments were designed to evaluate crops response: T1: Control, T2: Farmer's practice, T3: Recommended doses of all fertilizers except N, T4: Recommended doses of all fertilizers, T5: Urea briquette + other fertilizers, T6: NPK briquette + other fertilizers and T7: NPK briquette + other fertilizers except cowdung. The rate of urea and NPK briquette was 10 percent less than the rate of recommended prilled urea. The sizes of NPK and urea briquette were 3.4 g and 2.7 g, respectively. The recommended fertilizer doses were used to supply N, P, K, S, Zn and B from Urea, TSP, MoP, gypsum, zinc sulphate (hepta) and boric acid, respectively. The results showed that deep placement of NPK briquette gave significantly the highest yield of bitter gourd (32.16 tha^{-1}) followed by urea briquette (30.45 tha^{-1}) which were 12.34 and 7.41 percent higher over recommended doses of all fertilizers. The highest N recovery (77.4 %) was found when 72 kg N ha^{-1} was applied as NPK briquette

Choudhury *et al.* (2015) The performance was evaluated during April to November, 2012 of the deep placement of NPK fertilizer briquettes compared with broadcast incorporation of N, P, and K, with each treatment supplying S, Zn and B fertilizers as a blanket dose, for vegetables like cucumber, taro and bitter gourd. The experiments were conducted under on-station and on-farm conditions in three locations in Bangladesh: at Jessore for cucumber, at Patuakhali for bitter gourd and for taro at Mymensingh (onlyon-farm) and at

Jessore (only on-station). The size of the NPK briquettes and the urea briquettes was 3.4 g and 1.8 g, respectively. The results showed that deep placement of the NPK briquettes gave higher vegetable yields (28.8% for cucumber, 25.6% for taro and 10.8% for bitter gourd) and higher gross margins over broadcast incorporation of N, P, and K. The amount of NPK nutrient uptake and recovery by all three vegetable crops was also higher in the NPK briquette treatment compared to the broadcast treatment with PU, TSP and MOP.

Kokare, (2015) carried out a field study on a lateritic soils of Konkan for year (2010-2011) to study the effect of different fertilizer briquettes and organic manures on yield, nutrient uptake and chemical properties of soil in chilli (*Capsicum annuum* L.) in lateritic soils of Konkan. It is observed that the application of Urea-Godavari briquettes (3 briquettes per plant) first at transplanting, second at 30 DAT and third at 60 DAT was found significantly superior over rest of all the treatments in respect of yield. Application of Urea -Godavari briquettes first at transplanting, second at 30 DAT and third at 60 DAT recorded higher total N and P uptake while application of Urea-Suphala briquettes first at transplanting, second at 30 DAT and third at 60 DAT recorded higher total K uptake. The available nutrient status (N, P and K) in soil after harvest was found to be improved due to application of all three types of briquettes as compared to RDF and RDF based on soil test.

The experiment was conducted at Hazara Agricultural Research Station, Abbottabad, Pakistan during the year 2004-05. The most popular variety of potato "Desiree" was analyzed to find out the effect of different doses of NPK on its proximate composition. The results showed that NPK fertilizers had significant effect on nutrient composition of potato. Moisture content was in the range of 68.8 percent in T6 (140:140:210 NPK) to 81.4 percent in T2 (60:60:90 NPK). Crude protein contents were very low in potato, which were from 0.9percent in T1 (control)to 1.4 percent in T6 (140:140:210 NPK). Percent fats of potato dropped off by increasing the doses of NPK. Fat was lowest as 0.4 percent in T7 (160:160:240) and highest as 1.2 percent in T1 (control). The crude fiber in potato is enhanced by rising amount of NPK. The crude fiber and ash content were ranging from 1.99 (T5) to 3.59 (T7)percent and 3.68 (T7) to 5.18 (T5) percent respectively. From above results it is commended that right amount of NPK fertilizers should be applied to gain high yield and nutritious product.

Shah *et al*. (2013) carried out twelve experiments at the Bangladesh RiceResearch 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.

Naznin *et al*. (2013) investigate the effects of prilled urea (PU), urea super granule (USG) and NPK briquette on NH_4-N concentration in field water, yield and 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.

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.

There are several other studies dealing with the application of fertilizers in the form of super granules or briquettes, also with promising results, although the scientific literature mostly deals with fertilizer effects on rice, particularly as briquette fertilizers are gaining in popularity throughout sub-tropical and tropical Asia compared to surface applied urea (Khalil *et al*., 2011).

Islam *et al.* (2011) conducted an experiment at the Bangladesh Rice Research Institute, R/S Sagordi farm, Barisal to evaluate the effectiveness of NPK briquette on rice in tidal flooded soil condition during Boro season, 2010. The results showed that NPK briquettes, USG and PU produced statistically similar grain yield. N-treated plots (briquettes, USG and PU) gave significantly higher grain yield than N control. The highest grain yield (7.47 t ha-1) was observed in NPK briquette (2.4 g × 2) followed by PU. There was no significant difference between N control and absolute control plots in respect of yield indicating that N was the only yield limiting factor under that condition. 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 recommended PU. There was no residual effect of NPK briquettes on soil chemical properties. The NPK briquettes were found beneficial to the farmers in tidal ecosystem.

Application of urea and NPK briquette proved to be profitable in different upland crops such as tomato, cabbage, cauliflower and potato. By using of UDP technology, yield increased significantly with less use of urea about 10-20 percent as compared to prilled urea (OFRD, 2009)

Darade and Bankar (2009) conducted a field experiment during kharif season of 2006 at Agronomy Farm, College of Agriculture, Dapoli, on clay lateritic loam soil. Results of the experiment revealed that the deep placement of urea-DAP briquettes (@ 114 kg N + 25.4 kg P) + 50 kg K2O ha-1 recorded higher nitrogen, phosphorus and potassium uptake of 118, 29.0 and 95.58 kg ha^{-1}, respectively and grain yield (70.22 q ha^{-1}) which was significantly higher as compared to RDF (150:75:50 kg NPK ha^{-1}), deep placement of Urea-DAP briquettes (57 kg N + 12.7kg P) + 50 Kg K_2O ha^{-1} and control. Zinc levels also recorded significant effect on uptake of these nutrients and yield of hybrid rice. Soil application of $ZnSO_4$ @ 25 kg ha^{-1} produced significantly higher NPK uptake and yield of rice. Data also revealed that different levels of macronutrients and zinc levels interacted significantly in enhancing the grain yield of rice. Application of urea-DAP briquettes (@ 114 kg N + 25.4 kg P) + 50 kg K_2O ha^{-1} along with $ZnSO_4$ @ 25 kg ha^{-1} recorded significantly higher grain yield as compared to all other treatment.

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 ofconventional fertilizers (100-50-50 kg NPK ha-1).

Durgude *et al.* (2008) tested fertilizer briquettes with constant amounts of NP but with different amounts of K (56-30-0, 56-30-15, 56-30-30, 56-30-45, and 56-30-60 kg ha^{-1}) against surface applied fertilizer of 100-50-50 kg ha^{-1}. Although deeply placed 56-30-30 NPK briquettes proved to be the best fertilizer for rice grain and straw yield, all of the briquette combinations proved 15 better than the surface applied 100-50-50 NPK fertilizer each year of the test (2003–2005) in both grain and straw yield even though the surface applied fertilizer was applied in three split applications to reduce N losses.

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.

A national survey conducted in Bangladesh during 2004 showed that more than 1800 briquette-making machines had been manufactured and sold and about 550000 rice farmers were using the technology in their fields (IFDC., 2007).

In Bangladesh, yield of rice was increased by 15-25% while expenditure on commercial fertilizer was decreased by 24-32% when fertilizer briquettes were used as the source of plant nutrients. Deep placement of fertilizer briquettes also environmental and economic benefits (IFPRI. 2004)

Application of urea briquettes has proved to be proftable in different upland crops such as brinjal, tomato, cabbage, cauliflower, potato, maize and banana and the results to date have shown that 10–20% urea could be saved and the yield increased substantially by the use of urea briquettes instead of prilled urea (Hossain *et al.*, 2003).

Kadam (2001) found urea briquette fertilizer to be better than surface split applied urea in rice. The increase varied considerably from as little as 5 to 83% in rice grain yield. Either way, the briquettes were a better fertilizer option than urea surface applied as a split to decrease N losses. He further observed that it is possible to deeply place urea briquettes mechanically and achieve the agronomic efficiency obtained by hand placement of briquettes. This anticipates the feasibility of agronomic application of briquettes in developed countries where nearly all of agriculture is machine based.

Deep placement of N briquette at 8-10 cm depth of soil can save 30% N compared to Prilled Urea (PU), increases absorption rate, improves soil health and ultimately increases rice yield (Savant *et al.,* 1990).

2.5 Effect of NPK and Organic matters application on soil property

Hemalatha *et al.* (2000) revealed that green manure significantly increased the soil fertility status, organic carbon, available soil N, P and K at post harvest soil.

Zaman *et al.* (2000) reported that chemical properties like organic matter content CEC, total N, exchangeable K, available P and S were favorably influenced by the application of organic sources of nitrogen and potassium while the organic sources mostly did not show positive effect. Soil pH decreased slightly compared to the initial status. The literature review discussed above indicates that nitrogen and phosphorus fertilizer greatly influence the yield contributing characters and yield of rice. The properties of soils are also influenced by the inclusion of nitrogen and phosphorus fertilizer.

Nimbiar (1997) views that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining healthy soil fertility status. Intensive crop production systems have witnessed serious problems associated with loss of soil fertility as a result of excessive soil mining of plant nutrients and consequently reduction in productivity. Application of external source of plant nutrients is a key element in optimal management of soil organic matter, crop residues and manure for ensuring the bio-availability, the cycling and the balance of nutrients in the soil - plant systems.

Mathew and Nair (1997) reported that cattle manure when applied alone or in combination with chemical fertilizer (NPK) increased the organic C content, total N, available P and K in rice soils.

Sarker and Singh (1997) reported that organic fertilizers when applied alone or in combination with inorganic fertilizers increase the level of organic carbon in soil as well as the total N, P and K contents of soil.

Xu *et al.* (1997) observed that application of organic matters affect soil pH value as well as nutrient level. Santhi et al. (1999) observed that application of 100% NPK plus FYM decreased the bulk density and increased the water holding capacity of soil. The decreased in bulk density in FYM treated plots might be ascribed to better aggregation. The 14 water holding capacity was increased due to the improvement in structural condition of soil that was brought about mainly by the application of FYM in combination with NPK fertilizers.

Palm *et al.* (1996) stated that organic materials influence nutrient availability nutrients added through mineralization – immobilization pattern as energy sources for microbial activities and as precursors to soil organic matter and by reducing P sorption of the soil.

Medhi *et al*. (1996) reported that incorporation of organic and inorganic sources of N increased soil solution NH_4-N to a peak and then declined to very low levels.

Nahar *et al.* (1995) had examined the soil condition after one crop cycle (rice wheat). Addition of organic matter during the rice crop doubled the organic C content compared to its original status. Total and available N contents were also significantly improved by addition of organic matter, but had less impact on soil exchangeable cations.

Bhandari *et al.* (1992) reported that an application of fertilizers or their combined use with organic manure increased the organic C status of soil. The NPK fertilizers at 100% level and their combined use with organic N also increased the available N and P by 5.22 kg and 0.8-3.8 kg ha^{-1} from their initial values.

Meelu *et al.* (1992) reported that organic C and total N increased significantly when Sesbania and Crotolaria were applied in the preceded rice crop for two wet seasons.

Prasad and Kerketta (1991) conducted an experiment to assess the soil fertility, crop production and nutrient removal for cropping sequences in the presence of recommended doses of fertilizers and cultural practices along with 5 t ha^{-1} compost applied to the crops. There was an overall increase in organic C, increase in total N (83.9%), available N (69.9%), available P (117.3%) and CEC (37.7%).

Bair (1990) stated that sustainable production of crop can't be maintained by using chemical fertilizers only and similarly it is not possible to obtain higher crop yield by using organic manure alone. Sustainable crop production might be possible through the integrated use of organic manure and chemical fertilizers.

2.6 Literature about Vermicompost

The importance of composts as a source of humus and nutrients to increase the fertility of soil and growth of plant has been well recognized in the present study. Vermicompost and chemical fertilizer were taken first for chemical analysis and then to find the effect of these composts on the growth of SRI Rice Cultivation. It was found that the vermicompost was rich in nutrients like Potassium, Nitrate, Sodium, Calcium, Magnesium, and Chloride and have the potential for improving plant growth than Fertilizer. The optimal growth of SRI Rice in our study conducted for a period of four month. The study also showed distinct differences between vermicompost and chemical fertilizer in terms of their nutrient content and their effect on SRI Rice plant growth (Kandan and Subbulakshmi, 2015)

Kumar *et al*. (2014) carried out during kharif season of 2011 to study the effect of organic and inorganic sources of nutrient on yield, yield attributes and nutrient uptake of rice cv. PRH-10. Application of organic and inorganic sources of nutrient in combination remarkably increased yield, yield attributes and16 nutrient uptake of rice than alone. 125% RDF + 5 t/ha vermicompost recorded significantly higher yield, yield attributes and nutrient uptake in comparison to other treatments and this was followed by 100% RDF + 5 t/ha vermicompost. 125% RDF + 5 t/ha vermicompost was increased the number of panicles (20.50%), panicle length (23.12%), panicle wt. (13.02%), 1000 grain wt. (12.90%), grain yield (31.15%), straw yield (37.12%), protein content (18.77%), N uptake in grain (36.81%) and straw (42.81%), P uptake in grain (32.62%) and straw (31.56%) and K uptake in grain (35.46%) and straw (25.39%) over control. The lower yield, yield attributes, gross return and nutrient uptake was recorded in control.

Tharmaraj *et al.* (2011) studied the effect of vermicompost on soil chemical and physical properties was evaluated during samba rice cultivation studies. The physical properties such as, electrical conductivity (EC), porosity, moisture content, water holding capacity and chemical properties like nitrogen, phosphorous, potassium, calcium and magnesium were found distinctly enhanced in vermicompost treated soil, whereas the corresponding physicochemical values in control were minimum. The soil treated with vermicompost had significantly more electrical conductivity in comparison to unamended pots. The addition of vermicompost in soil resulted in decrease of soil pH. The physical properties such as water holding capacity, moisture content and porosity in soil amended with vermicompost were improved. The vermiproduct treated plants exhibit faster and higher growth rate and productivity than the control plants. Among the treated group, the growth rate was high in the mixture of vermicompost and vermiwash treated plants, than the vermicompost and vermiwash un-treated plants. The maximum range of some plant parameter's like number of leaves, leaf length, height of the plants and root length of plant, were recorded in the mixture of vermicompost and vermiwash. The results of this experiment revealed that addition of

vemicompost had significant positive effects on the soil physical, chemical properties and plant growth parameters.
Conjuctive use of vermicompost @ 2 t/ha along with 50 per cent N/ha enabled hybrid rice to produce grain yield at par that obtained by application of recommended dose of fertilizer along (Upendrarao and Srinivasulureddy, 2004).

A field experiment was carried out during wet season of 1997 to study the response of scented rice (cv. Pusa basmati1) to levels of NPK, vermicompost and growth regulator at ARS, Siraguppa. The results revealed that application of 150:75:75 NPK kg ha^{-1} has recorded significantly higher growth, yield attributes and yield (5261 kg ha^{-1}) as compared to lower levels of NPK. Scented rice Pusa Basmati-1 responded significantly to the organic manure. Application of vermicompost @ 5 t ha^{-1} resulted in significantly higher yield (4889 kg ha^{-1}) as compared to no vermicompost application. Significantly response was observed from spraying of triacontanol (GR) @ 500 ml ha^{-1} with respect to growth, yield attributes and yield (4861 kg ha^{-1}) as compared to spraying @ 250 ml ha^{-1} and water spray (Murali and Setty, 2004).
Vermicomposting is the bioconversion of organic waste materials into nutritious compost by earthworm activity and is an important component of organic farming package. Meena (2003) reported multifarious effects of vermicompost on growth and yield of crops.
Unlike other organic manures, vermicompost addition has got the added advantage of quick nutrient absorption by plants, to result in better dry matter accumulation. The increase in panicle number per m2 noted in the study was due to the promotion of tiller production with the supply of vermicompost (Sudha and Chandini, 2003). Application of vermicompost improved the chemical and physical structures of the soil. (Anitha and Prema, 2003).
Vasanthi and Kumaraswamy (1999) found that the soil organic carbon content increased with the treatment receiving vermicompost over the control.

Availability of nitrogen increased in earthworm cast application as compared to non-ingested soil.

Earthworms can live in decaying organic wastes and can degrade it into fine particulate materials, which are rich in nutrients. Vermicomposting is the application of earthworm in producing vermin-fertilizer, which helps in the maintenance of better environment and results in sustainable agriculture, earthworm make the soil porous and help in better aeration and water infiltration. Vermicompost can be prepared from different organic materials like sugarcane trash, coir pith, pressmud, weeds, cattle dung, bio digested slurry etc. Increased availability of nutrients in vermicompost compared to non-ingested soil resulted in significantly better growth and yield of rice has been reported by several workers (Sudhakar, *et al.*, 2002).

Application of vermicompost with fertilizer N and bio-fertilizer increased the rice yield by 16 per cent over the application of fertilizer N alone. Vermicompost applied with FYM recorded higher grain and straw yield of rice (Jeyabal and Kuppuswamy, 2001).

Ravi and Srivastava (1997) reported that combined application of vermicompost and inorganic fertilizers recorded significantly higher plant height, effective tillers per hill, seed and straw yield of rice, compared to application of inorganic fertilizer alone.

Gopal Reddy (1997) reported that vermicompost contains 1.98 per cent nitrogen 1.23 per cent phosphorus. 1.59 per cent potassium and 132, 70.5, 1440.2 and 317.5 mg per kg of total Zn, Cu, Fe and Mn, respectively.

Vasanthi and Kumaraswany (1999) reported that the seed yield of rice was significantly higher in the treatment that received vermicompost 5 t ha-1, along with recommended NPK application.

Vasanthi *et al*. (1995) reported that vermicompost application along with inorganic fertilizers increased the organic carbon content and available nitrogen status of soil by 87.7 and 42.9 percent, respectively.

Jadhav *et al.* (1993) reported that the water holding capacity and electrical conductivity of the soil were increased in the plots supplied with 5.0 t vermicompost per ha compared to control plots.

Hapse (1993) noticed that the organic carbon content of the soil increased by 0.27 per cent due to application of vermicompost compared to application of chemical fertilizer alone.

The vermicompost is an aerobically degraded organic matter which has undergone chemical disintegration by the enzymic activity in the gut of earthworms and so also enzymes of the associated microbial population. It has been found that use of vermicompost in field crops, vegetables, flowering plants and fruit crops has increased the yield and improved the quality with less disease and pest incidence (Baphna, 1992).

Kale *et al.* (1992) opined that vermicompost was like any other organic manure depending on the nature of wastes used as feed for worms. The nitrogen content varied between 0.5 to 2.0 per cent. Similar variation in respect of phosphorus and potassium content was also been reported. In the vermicompost production, the complex organic residues are bio-degraded by symbiotic association between earthworms and microbes. In the process of vermicompost, it helps to increase the density of microbes and also provides sufficient energy to remain active. Vermicasting will provide the vital macro nutrients viz., N, P, K, Ca, Mg, and micronutrients such as Fe, Mo, Zn, Cu etc. Apart from these, it also contains plant growth promoting substances like NAA, cytokinins, gibberellins etc. the chemical analysis of vermicompost produced at Dharwad revealed the availability of N, P, and K content at 0.8, 1.1 and 0.5 per cent, respectively

Kale *et al*. (1991) reported that application of vermicompost to summer paddy increased the uptake of nutrients and also increased the nitrogen and phosphorus contents of the soil. The application of vermicompost has long range influence on soil in improving chemical and biological properties.

Sudhakar (2016) conducted at Annamalai University, Experimental Farm, Annamalainagar, Chidambaram during two seasons to identify and evaluate different sources of vermicomposts on productivity enhancement, nutrient uptake and nitrogen use efficiency in low land rice under SRI method of cultivation The experiment comprised of eight treatments which includes recommend dose of fertilizer alone and in combination with vermicomposts prepared from various organic wastes namely Paddy straw, Coirpith, sewage sludge, Sugarcane trash, Pressmud and Crop residues @ 5t ha^{-1}. These were laid out in randomized block design and replicated thrice. Rice cultivar ADT 36 was used as the test variety. The results revealed that crop raised with pressmud based vermicompost registered higher grain, straw yield and harvest index. The vermicompost treatments had significant influence on the nutrient uptake, Nitrogen use efficiency (NUE) and Economic nitrogen use efficiency (ENUE) over control and recommended dose of fertilizer by the crop at harvest. Among the different organic source of vermicompost, pressmud based vermicompost registered the highest N, P, K uptake, nitrogen use efficiency (NUE) and economic nitrogen use efficiency (ENUE) values at harvest. From the above experimental results, it could be concluded that with application of pressmud based vermicompost @ 5.0 t ha^{-1} not only resulted in higher yields but also superior in respect of nutrient uptake and nitrogen economy under SRI method of rice cultivation.

Mahmud *et al.* (2016) studied the combined effect of vermicompost and chemical fertilizers on the nutrient content in grain, straw and post harvest soil of boro rice cv. BRRI dhan29, a field experiment was conducted in December, 2013 to June, 2014 at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Sixteen combinations of 4 vermicompost level @ 0, 1, 2, 4 t ha^{-1} and 4 NPKS levels i.e. 0-0-0-0, 50-8-33-6, 100-16-66-12, 150-24-99-18 kg ha^{-1}, respectively were applied. Results showed that the highest dose of vermicompost and chemical fertilizer increased the concentration of P, K and S by rice grain and straw significantly at the harvesting stage. Combined application of vermicompost and chemical fertilizer failed to increase the total N content of post-harvest soil. Combination of vermicompost and chemical fertilizers also increased the organic matter, P, K and S status of post harvest soil significantly.

Sultana *et al*. (2015) conducted an experiment to assess the effect of integrated use of vermicompost, pressmud and urea on the nutrient status of grain and straw of rice (Hybrid Dhan Hira 2). The highest amount of nitrogen (1.092%), phosphorus (0.297 %), potassium (0.374 %) in grain and the highest amount of potassium (1.213%), sulfur (0.091%) in straw were observed in plants receiving 90 kg N/ha from urea along with 30 kg N/ha from vermicompost. The highest sulfur (0.124 %) content in grain and the highest nitrogen (0.742%), the highest phosphorus (0.182 %) in straw was recorded in treatment 120 kg N/ha from urea. The highest amount of nitrogen (93.81 kg/ha), phosphorus (26.07 kg/ha), potassium (32.82 kg/ha) and sulfur (10.79 kg/ha) uptake by grains and the highest amount of nitrogen (55.70 kg/ha), phosphorus (13.79 kg/ha), potassium (92.43 kg/ha) and sulfur (6.91 kg/ha) uptake by straw of rice were observed in T_3 treatment. On the other hand the lowest values of these parameters were obtained from control treatment.

Dekhane, *et al.* 2014) conducted a trial with three replications and six treatments was laid out in Randomized Block Design to assess the performance of different organic and inorganic fertilizer on growth and yield of paddy crop (Variety GR 11) during Kharif season. Application of 50 % N through RDF + 50% N through vermicompost recorded higher growth attributes like plant height was 42.2 cm and 118.1 cm, no. of tillers per plant was 8.7 and 12.1 at 45 DAT and at harvest time respectively, panicle length (22.3 cm), grains per panicle (128.0), 1000-grain weight (19.7 g) and grain yield (4.97 t/ha.) and straw yield (5.77 t/ha.) of rice variety GR 11. The data clearly revealed that the yield obtained with treatment T5 (50% RDF + 50% N through vermicompost) was recorded significantly higher growth as well as yield attributes.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter includes the information regarding methodology that was used in execution of the experiment. The aim of the study was to evaluate the comparative effect of NPK briquettes and vermicompost on the yield and yield contributing characters of aromatic rice. A short description of location of the experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis etc. are presented in this section.

3.1 Experimental period

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the boro season of November 2018 to May 2019.

3.2 Description of the experimental site and soil:

3.2.1 Geographical location

The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.4 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.

3.2.2 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

2018 to May 2019 have been presented in Appendix II.

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.

3.2.3 Soil

The soil of the experimental field belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.8 to 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 for initial soil sample. The physicochemical properties of the soil in the experimental field are presented in table 1 and table 2..

Table 1. Morphological characteristics of the experimental field.

Morphology	Characteristics
Location	SAU Farm. Dhaka
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Shallow 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)	 22.52 56.74 20.74
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.9
Organic C (%)	0.681
Organic Matter (%)	1.17
Total N (%)	0.07
Exchangeable K(cmol kg-1)	0.131
Available P (mg kg-1)	19.83
Available S (mg kg-1)	14.45

3.3 Experimental Details

3.3.1 Planting Material

BRRI Dhan50 (Banglamoti), a high yielding variety of aromatic rice was used as a test crop. The variety was developed by hybridization method by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The variety was released in 2008 for cultivation in boro season.

3.3.2 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 7 different treatments combinations. Each block was subdivided into 7 unit plots and the treatments were randomly distributed to the unit plot in each block. Thus the total number of unit plot was 21. 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 Figure 1.

Treatments: There were seven treatments as follows,

- T_1= No fertilizer (control)
- T_2= Recommended fertilizers (Urea 290 kg/ha, TSP 110 kg/ha, MoP 100 kg/ha)
- T_3= NPK briquettes as recommended
- T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost
- T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost
- T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost
- T_7= 100% Vermicompost (20 ton/ha)

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. Pregerminated seed were sown in wet nursery bed on 25th November, 2018. 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 2018 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. No fertilizer was applied to the plot T_1. T_2 was fertilized as per recommended fertilizer by BRRI as 290 kg urea/ha (Urea: 261g per plot), 110 kg TSP/ha (TSP: 99g per plot) and 100kg MoP/ha (MoP: 90g per plot). One third of urea and all the other fertilizer was applied as basal dose. Remaining urea was applied as two top dressing at 35 DAT and 55 DAT. NPK briquettes was applied as one briquettes per hill. As 100% NPK 60 briquettes (60x2.4g= 144g) were applied T_3; as 75% NPK, 45

Briquettes (108 g) applied to T_4; as 50% NPK 30 briquettes (72 g) to T_5 and as 25% briquettes, 15 briquettes (36 g) were applied to T_6. In case of vermicompost as 100% NPK from vermicompost, 18 kg vermicompost was added to T7 treated plot as 75% NPK from vermicompost, 13.5 kg per plot to T_6; as 50% NPK from vermicompost, 9 kg per plot to T_5 and as 25% NPK from vermicompost, 4.5 kg per plot to T_4.

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 dhan50 were carefully uprooted from the seedling nursery and transplanted on 27 December, 2018. Three seedlings $hill^{-1}$ were used following a spacing of 15 cm × 25 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.

3.3.7.1 Gap filling

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

3.3.7.2 Weeding

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

3.3.8 Application of irrigation water

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

3.3.9 Method of water application

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

3.3.10 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, 2019. Crop was protected from birds by net during the grain filling period.

3.3.11 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 thatconsiderable losses by pest should be minimized. The field looked nice withnormal 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 10 May, 2019 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

- Plant height (cm)
- Total no. of tiller per hill
- Number of effective and
- Ineffective tiller per heel
- Panicle length (cm)
- Days to panicle initiation
- Number of filled and
- Unfilled grain per panicle
- 1000 grain weight
- Grain yield (ton/ha)
- Straw yield (ton/ha)
- Harvest index

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.

Total tillers per hill

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

Effective tillers per hill

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

Non-effective tillers per hill

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

Days to panicle initiation

Time of flowering was considered when emergence of panicle of 50% of the total plants within a plot took place. The number of days for panicle initiation was recorded.

Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

Filled grains per panicle

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 per panicle was recorded.

Unfilled grains per panicle

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 per panicle was recorded.

Weight of 1000 grain

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

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}.

Straw weight t ha^{-1}

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.

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.

Harvest index

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

3.6 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:

3.6.1 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).

3.6.2 Organic matter

Organic carbon in soil was determined by wet oxidation method of (Page *et al.*, 1982). 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.

3.6.3 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 2000C and added 3 ml H_2O_2 and then heating at 3600C 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

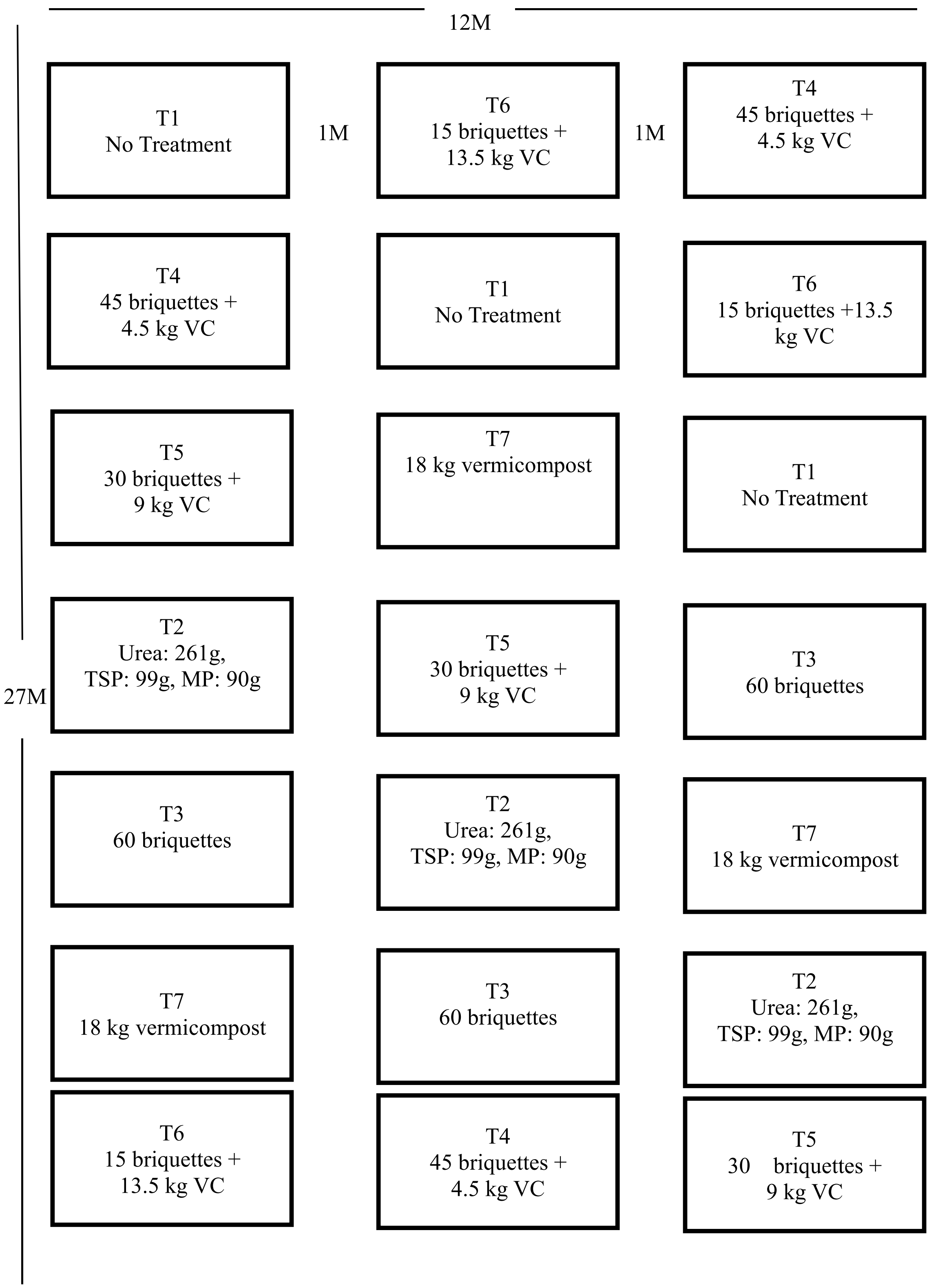
Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen et al., 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings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

3.6.4 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).

3.7 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 dhan50. The mean values of all the characters were calculated and analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using Statistix 10 computer software. The significance of the difference among the treatment means was compared using the Least Significant Difference (LSD) (Gomez *et. al*., 1984).



Total Area = 27 x 12 m^2

Plot Area = 9 m^2

Spacing = 15 cm x 25 cm

Figure 1: Layout of the experiment

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The research work was accomplished to observe the comparative effect of NPK briquettes and vermicompost on the yield and yield contributing characters of aromatic rice (*Oryza sativa* L.) showed differences in terms of different characters.

4.1 Plant Height

Plant height significantly differed within the different types of fertilizer management practices at different days after transplanting (Appendix: II). Finally Longest plant was found with the treatment T_4 (97.2 cm) and the shortest plant was found in treatment T_1 (68.3 cm) (Figure 2). Roy (2019) Naznin *et al*. (2013) and some other also found the similar findings.

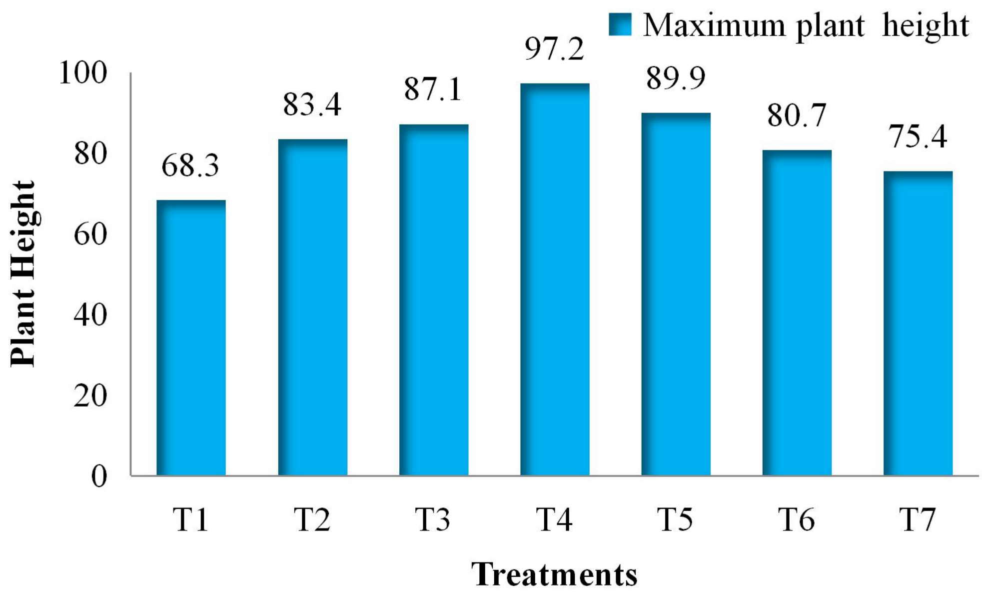


Figure 2. Effect of different types of fertilizer management on plant height at different days after transplanting

T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha).

4.2 Number of tiller per hill

Number of tiller per hill of rice plants significantly differed among the different types of fertilizer management practices (Appendix: II). Maximum number of tiller per hill was found with T_4 (38.19) treatment and the minimum was found in T_1 (26.48) (Table 3). Higher number of tiller is very important for higher production. Higher no of tiller represents better vegetative growth. Nutrient supply is prerequisite for better vegetative growth which may result in higher number of tiller. NPK briquettes are slow releasing chemical fertilizer which reduces the leaching loss of nutrients. As a result nutrients are available for a long period of time. On the other hand vermicompost improves the soil structure and texture which provide a better soil environment for better root growth (Hemalatha *et al.* 2000). Results found by Roy (2019); Rahman *et al*. (2016); Choudhury *et al.* (2015) and Islam *et al.* (2011) are supporting to this result.

4.3 Number of effective tillers per hill

Significant variation was found among the different types of fertilizer management treated plants in case of number of effective tillers per hill. (Appendix: II). Maximum number of effective tillers per hill was obtained from treatment T_4 (35.7) where as treatment T_1 (20.1) showed minimum number of effective tillers per hill (Table 3). From this study it was observed that plants applied with 75% NPK as NPK briquettes with 25% NPK from vermicompost produced maximum number of effective tillers per hill. On the other hand number of effective tillers per hill was minimum incase of control treatment. Higher the no. of effective tillers produces higher no. of panicle and finally results higher yield. NPK briquettes and also the vermicompost are slow releasing fertilizer. That’s why nutrient availability last for a long time. Vermicompost as an organic manure provides better soil condition. May due to this reason plants produced higher no. of effective tillers with NPK and vermicompost application. Tapkeer, (2017); Akter *et al.* (2015) and Kokare, (2015) also found the similar result.

4.4 Number of ineffective tillers per hill

Significant variation was found among the different types of fertilizer management treated plants in case of number of ineffective tillers per hill. (Appendix: II). The maximum number (6.38) of ineffective tillers per hill was obtained from T_1. On the other hand treatment T_4 produced the minimum number (2.49) of ineffective tillers per hill (Table 3). From this study it was observed that plants with no fertilizer produced the maximum number of ineffective tillers per hill, and number of ineffective tillers per hill was the minimum incase of 75% NPK as NPK briquettes and 25% NPK from vermicompost. Roy (2019) and Naznin *et al*. (2013) also reported result similar to this.

4.5 Days to panicle initiation

Days to panicle initiation significantly varied among the different water management practices (Appendix: II). The earliest panicle initiation (64.1 days) was observed by treatment T_4. On the other hand treatment T_1 took the longest period (76.7 days) for panicle initiation (Table 3).This study presented that 75% NPK as NPK briquettes and 25% NPK from vermicompost initiated the panile in earliest period. Whereas plants of control treatments took longest time to Initiate panicle. Tapkeer, (2017); Rahman *et al*. (2016); Choudhury *et al.* (2015) and Kokare, (2015) reported similar kind of finding.

Table 3. Effect of different fertilizer management treatments on rice related to quality attributes

Treatments[x]	Total number of tiller per hill		Number of Effective tiller per hill		Number of ineffective tiller per hill		Days to panicle initiation	
T_1	26.48	d	20.1	f	6.38	a	76.7	a
T_2	30.7	c	26.2	d	4.5	c	72.2	bc
T_3	32.0	c	27.9	c	4.1	d	71.7	bc
T_4	38.2	a	35.7	a	2.5	f	64.1	d
T_5	35.7	b	32.1	b	3.6	e	68.7	c
T_6	30.1	c	25.3	de	4.8	bc	72.5	b
T_7	29.8	c	24.7	e	5.1	b	72.9	b
$LSD_{0.05}$	2.5		1.1		0.4		3.7	
C.V. %	4.4		2.2		5.0		5.3	

x: T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha)

4.6 Panicle length

Rice plants expressed significant difference among the different types of fertilizer management practices in case of panicle length. (Appendix II) From this study it was observed that treatment T_4 produced the longest panicle (22.9 cm) which was statistically similar with treatment T_2 (22.4 cm), T_3 (22.5 cm) and T_5 (22.7 cm). On the other hand treatment T_1 (20.7cm) produced the shortest panicle (Table 4). From this research it was observed that applying 75% NPK as NPK briquettes with 25% NPK from vermicompost had the longest panicle. Roy (2019); Rahman *et al*. (2016) and Naznin *et al*. (2013) also found this type of result.

4.7 Number of filled grains per panicle

Number of filled grains per panicle was significantly affected by different types of fertilizer management treatments (Appendix: II). Among the seven treatments, treatment T_4 gave the highest number (104.6) of filled grains per panicle and where as the lowest number (86.3) of filled grains per panicle was obtained fromthe treatment T_3 (Table 4). Study reveals that 75% NPK as NPK briquettes + 25% NPK from vermicompost had the maximum number of filled grains per panicle. Proper nutrient supply at filling stage is very important for grains to be filled. Primary nutrients like nitrogen, potassium, phosphorus etc are supplied as fertilizer and the other nutrients are more or less available in soil. NPK briquettes contains satisfactory amount of N, P and K. On the other hand vermicompost is also rich in these types of nutrients. Vermicompost also contain other essential nutrients though in less amount. As an organic matter, vermicompost also improves soil properties, increase the uptake of nutrient and water by the plant thus results in higher rate of photosynthesis (Hemalatha *et al.* 2000). Production of food material and their transportation to the storage site results in the grain to be filled. Winings (2014); Islam *et al.* (2011) and Darade and Bankar (2009) found the similar results.

4.8 Number of unfilled grains per panicle

Significant variation was found among the different types of fertilizer management treatments in case of number of unfilled grains per panicle (Appendix: IV). Among the seven types of fertilizer management treatments T_1 showed highest number (27.6) of unfilled grains per panicle and treatment T_4 showed lowest (22.0) (Table 4). This study reveals that the plants supplied with no fertilizer produced the maximum no. of unfilled grain. Unavailability of nutrient is the main constrain to the grains to be filled. Rice plant needs a large amount of nutrient supply apart from those available within the soil itself, this might be the reason why plants lack of nutrient supply failed to fill the grain and thus produced higher number of unfilled grain. Similar observation was happened with Roy (2019); Rahman *et al*. (2016); Naznin *et al*. (2013); Islam *et al.* (2011) and Darade and Bankar (2009).

4.9 Weight of 1000-seed

Significant variation in thousand seed weight was found among the different treatments (Appendix: III). From the above study we found that treatment T_4 produced the maximum weight (20.3 g) of 1000-grain. On contrary treatment T_1 produced the minimum Weight (16.3 g) of 1000-grain (Table 4). From this research it was observed that plants supplied with 75% NPK as NPK briquettes + 25% NPK from vermicompost had the maximum weight of 1000-seed, the plant managed with no supply of nutrient had the minimum weight of 1000-seed. Higher the weight of thousand grain weight represents better grain yield. Grain quality is also determined by the thousand grain weight. The grain weight to be higher, supply of photosynthetic food material produced by plant itself need to be sufficient at the storage point, which require higher rate of photosynthesis. Winings (2014); Naznin *et al*. (2013); Islam *et al.* (2011); Darade and Bankar (2009) and Zaman *et al.* (2000) found the similar results.

Table 4. Effect of different fertilizer management treatments on rice related to quality attributes

Treatments[x]	Panicle Length (cm)	Number of filled grains per panicle	Number of unfilled grains per panicle	1000 seed weight (g)
T_1	20.7 a	86.3 e	27.6 a	16.3 e
T_2	22.4 a	95.1 cd	24.9 bc	18.1 cd
T_3	22.5 a	97.3 bc	24.6 cd	18.2 bc
T_4	22.9 a	104.6 a	22.0 e	20.3 a
T_5	23.7 a	98.7 b	23.9 d	18.7 b
T_6	22.4 a	93.8 cd	25.1 bc	17.8 cd
T_7	22.3 a	92.4 d	25.7 b	17.5 d
$LSD_{0.05}$	2.2	5.7	1.8	1.1
C.V. %	2.8	3.4	4.0	3.5

x: T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha)

4.10 Grain yield per hectare

Grain yield per hectare was significantly affected by different types of fertilizer management treatments (Appendix: III). Among the all fertilizer management treatments T_4 produced the highest grain (6.7 t) yield per hectare and where as the lowest grain (3.41 t) yield per hectare was produced by T_1 (Table 5). From this research it was observed that 75% NPK as NPK briquettes + 25% NPK from vermicompost produced the maximum grain yield per hectare. On the other hand control produced the minimum grain yield. Food materials synthesized in leaf but stored in grain. Adequate nutrient supply serves for the synthesis materials prerequisite for photosynthesis and finally assists to increase the photosynthesis rate. Vermicomposts contains different types of enzymes which influences the proper growth of plant. Nutrient and water uptake is high when organic manure is in adequate in soil. Supply of nutrient with organic matter helps to higher productivity (Zaman *et al.* 2000). Naznin *et al*. (2013); Roy (2019); Tapkeer, (2017); Rahman *et al*. 2016; Choudhury *et al.* (2015); Akter *et al.* (2015); Kokare, (2015) and some other researcher also found the similar results.

4.11 Straw yield per hectare

Rice plants expressed significant difference among the different types of fertilizer management treatments in case of straw yield per hectare (Appendix: III). From this research it was observed that T_4 showed highest straw (7.1 t) yield per hectare and T_1 showed the lowest (4.5 t) (Table 5). This study presented that by applying 75% NPK as NPK briquettes and 25% NPK from vermicompost maximum straw yield per hectare was obtained. On the other hand due to applying no fertilizer, straw yield per hectare was minimum. Higher the vegetative growth, higher the straw yield. Application of NPK fertilizer and verimicompost was sufficient which resulted in better vegetative growth (Zaman *et al.* 2000). Nitrogen is the most important for chlorophyll production thus photosynthesis. Potassium and phosphorus is also important for photosynthesis process. Altogether help in a better vegetative growth. Vermicompost with nutrient supply also provide better root growth condition which helps in nutrient uptake and finally higher straw yield. Tapkeer, (2017); Akter *et al.* (2015); Kokare, (2015); Winings (2014); and Islam *et al.* (2011) and Darade and Bankar (2009) also reported the similar result.

4.12 Total biological yield

Significant variation among the different types of fertilizer management treatments was observed in case of total biological yield (Appendix: III). From this research it was observed that T_4produced the highest amount (13.8 t) of total biological yield on the other hand T_1 produced the lowest amount (7.8 t) of total biological yield (Table 5). From this research it was found that 75% NPK as NPK briquettes and 25% NPK from vermicompost produced the maximum biological yield. On the other hand plants with control treatment produced the minimum biological yield. Similar result is found by Roy (2019); Winings (2014); Naznin *et al*. (2013); Islam *et al.* (2011) and Darade and Bankar (2009) and some other.

4.13 Harvest index

Significant variation was found among the different types of fertilizer management treatments in case of harvest index of rice plants (Appendix: III). Among the four types of fertilizer management treatments T_4 showed the best harvest index (48.1%) and T_1showed lowest harvest index (43.9g) among the treatments (Table 5). From this research it was observed that 75% NPK as NPK briquettes + 25% NPK from vermicompost performed best in case of harvest index and the plants with control performed worst. Roy (2019); Tapkeer, (2017); Choudhury *et al.* (2015); Akter *et al.* (2015); and Kokare, (2015);
Found the similar result.

Table 5. Effect of different fertilizer management treatments on rice related to quality attributes

Treatments[x]	Grain yield per hectare (t)	Straw yield per hectare (t)	Total Biological yield per hectare (t)	Harvest Index (%)
T_1	3.4 e	4.5 f	7.8 f	43.9 d
T_2	5.0 c	5.8 cd	10.8 d	46.5 bc
T_3	5.2 bc	6.1 c	11.3 c	46.0 bc
T_4	6.7 a	7.1 a	13.8 a	48.9 a
T_5	5.6 b	6.6 b	12.2 b	45.9 c
T_6	4.8 c	5.6 de	10.4 d	47.4 b
T_7	4.3 d	5.2 e	9.5 e	46.6 bc
$LSD_{0.05}$	0.4	0.4	0.4	1.4
C.V. %	4.5	4.0	2.3	1.8

x: T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha)

4.14 Post-Harvest properties of soil

4.14.1 pH of Post-Harvest Soils

No significant variation was recorded in post-harvest soil pH due to the application of different fertilizer management for BRRI Dhan50 (Banglamoti) cultivation (Appendix: IV). Although there were no significant difference among the treatments, the highest pH (6.17) of post-harvest soil was found from T_3 (NPK briquettes as recommended) which was statistically identical with others. The lowest pH (6.07) of post-harvest soil was recorded from T_1 control (No fertilizer).

4.14.2 Organic matter of post-harvest soil

Table 6 is showing the effects of different types fertilizer management on organic matter status of post-harvest soils (Appendix: IV). It was found that organic matter status of post-harvest soil statistically significant. The maximum organic matter (1.42%) of post-harvest soil was found from T_7 (100% NPK from vermicompost) which was statistically similar with T_6 (1.38%). The lowest pH (1.22) of post-harvest soil was recorded from T1 control (No fertilizer)

4.14.3 Total N

Total N in post-harvest soil showed statistically significant differences due to the effect of different treatments (Appendix: IV). The highest (0.068%) total N was found from T_3 treatment which was statistically similar (0.065%) to T_4 treatment while the lowest (0.022 %) soil total N was observed from T_1 treatment (Table 6).

4.14.4 Available P

Available P in post-harvest soil showed statistically significant differences due to the effect of different treatments (Appendix: IV). The highest (38.64 ppm) available P was observed from T_4 treatment, whereas the lowest (16.41 ppm) available P was found from T_1 treatment.

4.14.5 Exchangeable K

Statistically significant difference was recorded in terms of exchangeable K in post-harvest soil due to different treatments (Appendix: IV). The highest (0.172 meq/100 g soil) exchangeable K was observed from T_4 treatment, and the lowest (0.121 meq/100 g soil) exchangeable K was recorded from T_1 treatment which was statistically similar (0.131 meq/100 g soil) to T_7.

Table 6. Effect of different fertilizer management treatments on post-harvest soil properties

Treatments[x]	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq/100 g soil)
T_1	6.0 a	1.22 d	0.022 f	16.41 e	0.121 d
T_2	6.2 a	1.24 cd	0.061 bc	33.12 c	0.133 c
T_3	6.1 a	1.26 cd	0.068 a	36.70 ab	0.145 b
T_4	6.1 a	1.31 bc	0.065 ab	38.64 a	0.172 a
T_5	6.1 a	1.34 b	0.058 c	35.34 bc	0.135 bc
T_6	6.1 a	1.38 ab	0.053 d	33.23 c	0.132 c
T_7	6.0 a	1.42 a	0.041 e	29.41 d	0.131 cd
$LSD_{0.05}$	0.71	0.074	0.0047	2.69	0.0101
C.V. %	6.49	3.17	4.1	4.75	5.03

x: T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha)

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMERY AND CONCLUSION

Rice is needed a high amount of fertilization for better production. Mentionable amount of nutrient is lost from the soil in various ways like runoff, fxation, leaching, and volatilization. Reduction of organic matter is also a major constrain to the productivity of soil in Bangladesh. So it's necessary to adopt some new technique to overcome these problems.

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 2018 to May 2019, with a view to observe the comparative effect of npk briquettes and vermicompost on the yield and yield contributing characters of aromatic rice (*Oryza sativa* L.) showed differences in terms of different characters at boro season under the Modhupur Tract (AEZ-28).

There were altogether seven treatment combinations consisting of different source of NPK comprising NPK briquettes and vermicompost. Treatments were T_1= No fertilizer (control), T_2= Recommended fertilizers, T_3= NPK briquettes as recommended, T_4= 75% NPK as NPK briquettes + 25% NPK from vermicompost, T_5= 50% NPK as NPK briquettes + 50% NPK from vermicompost, T_6= 25% NPK as NPK briquettes + 75% NPK from vermicompost, T_7= 100% Vermicompost (20 ton/ha).

Finally Longest plant was found with the treatment T_4 (137.2 cm) and the shortest plant was found in treatment T_1 (108.3 cm). Maximum number of tiller per hill was found with T_4 (38.19) treatment and the minimum was found in T_1 (26.48). Maximum number of effective tillers per hill was obtained from treatment T_4 (35.7) where as treatment T_1 (20.1) showed minimum number of effective tillers per hill. The maximum number of ineffective tillers per hill was obtained from T_1 (6.38). On the other hand treatment T_4 (2.49) produced the minimum number of ineffective tillers per hill.

Treatment T_4 (23.7 cm) produced the longest panicle which was statistically similar with treatment T_2 (22.7 cm), T_3 (22.8 cm) and T_5 (23.0 cm). On the other hand treatment T_1 (20.7cm) produced the shortest panicle. The earliest panicle initiation was observed by treatment T_4 (64.1 days). On the other hand treatment T_1 took the longest period for panicle initiation (76.7 days).

Among the seven types of fertilizer management treatments T_4 (104.6) gave the highest number of filled grains per panicle and where as the lowest number of filled grains per panicle was obtained from the treatment T_3 (86.3). On the other hand treatment T_1 (27.6) showed highest number of unfilled grains per panicle and treatment T_4 (22.0) showed lowest. Treatment T_4 (20.3 g) produced the maximum weight of 1000-grain. On contrary treatment T_1 (16.3 g) produced the minimum Weight of 1000-grain.

Treatment T_4 (6.7 t/h) produced the highest grain yield per hectare and where as the lowest grain yield per hectare was produced by T_1 (3.41 t/h). Treatment T_4 (7.1 t/h) showed highest straw yield per hectare and T_1 (4.5 t/h) showed the lowest. T_4 (13.8 t/h) produced the highest amount of total biological yield on the other hand T_1 (7.8 t/h) produced the lowest amount of total biological yield. Treatment T_4 (48.1%) showed the best harvest index and T_1 (43.9%) showed lowest harvest index among the treatments.

Conclusion

Regarding as the above results it can be concluded that T_4 (Conventional flooding method) and T_4 (75% NPK as NPK briquettes with 25% NPK from vermicompost) performed best in case of most of the vegetative and yield characteristics like Plant height, Panicle length, Number of effective and Ineffective tiller, Number of filled and Unfilled grain, 1000 grain weight, Grain and Straw yield and Harvest index. Therefore, the treatment T4 (75% NPK as NPK briquettes with 25% NPK from vermicompost), can be recommended for successful cultivation of boro rice (BRRI dhan50).

REFERENCES

REFERENCES

Ahmad, A., (1996). Relative efficiency of MOP and SOP for wheat production. M.Sc. Thesis, *Deptt. Soil Sci.*, Univ. Agri., Faisalabad

Akter, H., Tarafder, S.K., Huda A. and Mahmud A.A. (2015). Effect of Prilled Urea, Urea and NPK Briquettes on the Yield of Bitter Gourd inTwoUpazillas of Jessore District. *Environ. Sci. & Natural Resour.*, 8(1): 157-160.

Angayarkanni, A. and Ravichandran, M. (2001). Judicious fertilizer N split for higher use efficiency in transplanted rice. *Indian. J. Agric. Res.,* 35(4): 278-280.

Anitha, S. And Prema, A. (2003). Vermicompost boosts crop production. *Indian Farming*, 53 (8):15-17.

Ansari, A., (2007). Urban planning and environment strategies and challenges Macmillan India Pltd., *New Delhi*, pp. 277-279.

Arancon Q.N., Edwards C.A. (2009). The utilization of vermicompost in Horticulture and Agriculture. In: Edwards CA, Jeyaraaj R, Indira AJ (Eds.) Vermitechnology in Human welfare. RohiniAchagam, Coimbatore, Tamil Nadu, India, pp 98-108.

Bahmanyar, M.A. and. Mashaee, S.S. (2010). Influence of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice. *African J. Bitech*., 9 (18):2648-2653

Bair, W. (1990). Characterization of the environment for sustainable agriculture in semi arid tropic. In Proc.: Sustainable Agriculture : Issue. Perspective and prospect in Semiarid tropics. Singh. R. D. Ed, Hydrabad India. *Indian Soc. Agron*. 1: 90-128.

Baphna, P.D., (1992), Organic farming in sapota, Proceedings of National Seminar on Organic Farming, Mahatmapule Krishividyapeeth, *College of Agric.*, Pune, 23 : 79-83.

BARI, (2009). Application of urea super granule (USG) in tomato, cabbage, cauliflower, brinjal, potato, maize and banana: A profitable technology. A booklet (in Bengali) published by On-Farm *Res. Div. BARI*, Gazipur, Bangladesh.

Bayan, H.C. and Kandasamy, O.S. (2002). Effect of weed control methods and split application of nitrogen on weed and crop in direct seeded puddle rice. *Crop Res. Hisar*., 24(2): 266-272.

Bhandari, A.L., Sood, A., Sharma, K.N. and Rana, D.S. (1992). Integrated Nutrient Management in Rice-Wheat System. *J. Indian Soc. Soil Sci*., 40: 742-747.

Bhuiyan, N.I. and A.L. Shah. 1990. Effect of N fertilizer management and population density on nitrogen fertilizer use effciency in irrigated rice. *Bangladesh Rice J*. 1: 48–54.

Bulbule A.V., Durgude A.G., Patil V.S. and Kulkarni R.V., (2008). Fertilization of low land transplanted rice through briquettes. *Crop Res.* 35(1&2) 1-5.

Choudhury, A.K., Sarker, M.J.U., Rashid, M.H., Rashid, M.M., Sahiduzzaman, M., Islam, M.S., and Khairul, H. M. (2015) Bashar Response of Vegetables to NPK Briquette Deep Placement. *Kasetsart J. (Nat. Sci.)* 49 : 1 – 11

Darade, A.B. and Bankar, K.B. (2009). Effect of Urea-DAP briquettes and zinc levels on nitrogen, phosphorus and potassium uptake and yield of hybrid rice. *Int. J. Agric.Sci.* 5(2):510-512.

Dekhane, S.S., Patel, D.J., Jadhav, P.B., Kireeti, A., Patil, N.B., Harad, N.B. and Jadhav, K.P. (2014). Effect of organic and inorganic fertilizer on growth and yield of paddy CV GR 11. *Intel J. Information Res. and Review*.1 (2): 026-028.

Dobbermann, A., Cassman, K.G., Mamarialand C.P. and Sheehy, J.E. (1998). Management of phosphorus, potassium and sulfur in intensive, irrigated lowland rice. *Field Crop Res.* 56:113-138.

Dobermann A., Cassman, K.G.,Mamaril, C.P. and Sheehy, S.E. (1998). Management of Phosphorus,Potassium and sulfur in intensive irrigated lowland rice. *Field Crops Res.*56: 113-358.

Duhan, B.S. and Singh, M. (2002). Effect of green manuring and nitrogen on the yield and nutrient uptake of micronutrient by rice. *J. Indian Soc. Soil Sci*., 50(2): 178-180.

Dunn, D.J. and Stevens, G. (2008). Response of rice yields to phosphorus fertilizer rates and polymer coating. *J. Agril. Sci.*, 42(3): 34-37.

Durgude, A.G., Patil, Y.J. Bulbule, A.V. and Patil. V.S. (2008). Effect of fertilizer management through urea-DAP briquettes on lowland rice. *An Asian J. of Soil Sci.* 3:1–3.

Geethadevi, T., Gowada, A., Vidyachandra, B. and Babu, B.T.R. (2000). Studies on spilts application of nitrogen and their timing on growth and yield of rice genotypes, *Current Res. Univ. Agril. Sci*., 29 (3-4): 42-44.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). *Int. Rice Res. Inst., A Willey Int. Sci.,* p. 28-192.

Gopal, Reddy, B. (1997) Soil health under integrated nutrient management in maize soybean cropping system. Ph.D. Thesis, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad.

Hapse, D.G. (1993). Organic farming in the light of reduction in use of chemical fertilizers. Proceedings of 43rd Annual Deccan Sugar Technology Association, Pune, Part 1: 37-51.

Hemalatha, M., Thirumurugan, V., Joseph, M. and Balasubramanian, R. (2000). Accelaration of decomposition of paddy straw through bacteria, fertilizer, amendments and its influence on growth and yield of rice. *J. Maharashtra Agril. Univ*., 25(3): 267-269.

Hidlago, P.R., Matta, F.B and Harkess, R.L. (2006). Physical and Chemical properties of substrates containing earthworm castings and effects on marigold growth. *Hort sci*., 41: 1474- 1476

Hossain, M.J., M.Y. Ali, M.A. Rahman, M.A.H. Khan and M.M. Rahman. 2003. Application of urea super granule (USg) in vegetable crops: A proftable technology (Booklet). *On-Farm Res. Div.,* BARI. Gazipur, Bangladesh.

IFDC (2007). Mitigating poverty and environmental degradation through nutrient management in South and Southeast Asia. IFDC Report, International Fertilizer Development Center, Alabama, USA., March 2007.

IFPRI (2004). Annual report, 2003-2004. International Food Policy Research Institute (IFPRI), Washington, DC., USA., pp: 1-74

IFPRI., (2004). Annual report, 2003-2004. International Food Policy Research Institute (IFPRI), Washington, DC.USA. pp: 1-74.

Islam, M.R., Saha, P.K., Zaman, M.J. and Uddin, S.K. (2010). Phosphorus fertilization in inbred and hybrid rice. *J. of Biol. Sci.* 19(2): 181-187

Islam, M.S., Rahman,F. and Hossain, A.T.M.S. (2011). Effects of NPK briquette on rice (Oryza sativa) in tidal flooded ecosystem. *Agriculturists.* 9: 37-43.

Islam, M.S.H., Rahman, F. and Hossain, A.T.M.S. (2011). Effects of NPK Briquette on Rice (*Oryza sativa*) in tidal flooded ecosystem. *The Agriculturists*. 9(1 &2):37-43.

Ismail, S.A. (1997). Vermi cology: The biology of earthworms orients Longman press, Hyderabad, pp. 92.

Jadhav, S.B., Jadhav, M.B., Joshi, V.A. and Jagatap, P.B., (1993). Organic farming in the light of reduction in use of chemical fertilizers. Proceedings of 43rd Annual Deccan Sugar Technology Association, Pune, Part 1: SA 53-65.

Jeyabal and Kuppuswamy, (2001), Recycling of organic wastes for the production of vermicompost and its response in rice-legume cropping system and soil fertility. *European J. Agron*.,15 (3): 153-170.

Kadam, J.R. (2001). Efficient use of NPK fertilizer briquettes on the yield and quality of crops. *Indian Sugar* 51:115–118.

Kale, R.D., Bano, K. and Satyavati, G.P. (1991). Influence of vermicompost application on growth and yield of cereals, vegetables and ornamental plants. Final report of KSCST Project No. 67-04/verm/34B (3478), Bangalore, pp. 87.

Kale, R.D., Mallesh, B.C., Bano, K. and Bagyaraj, D.J. (1992). Influence of vermicompost application on available micronutrients and selected microbial population in a paddy field. *Soil Biol. and Bioch.*, 24 (12) : 1317-1320.

Kandan, T. and Subbulakshmi. (2015). Chemical Nutrient Analysis of Vermicompost and Their Effect on the Growth of SRI Rice Cultivation. *Intel J. Innovative Res. . Sci., Engineering and Tech.* 4 (6): 4382-4388.

Kapoor V., Singh U., Patil S.K., Magre H., Shrivastava L.K., Mishra V.N., Das R.O., Samadhiya V. K., Sanabria J. and Diamond R. (2008). Rice growth, grain yield, and floodwater nutrient dynamics as affected by nutrient placement method and rate. *Agron. J.* 100: 526-536.

Khalil, M. I. Schmidhalter, U. Gutser, R. and Heuwinkel, H. 2011. Comparative efficacy of urea fertilization via supergranules versus prills on nitrogen distribution, yield response and nitrogen use efficiency of spring wheat. Journal of Plant Nutrition, 34(6): 779-797.

Kokare, V.G., Kasture, M.C., Palsande V.N., and Mhalshi, R.M. (2015). Effect Of Different Fertilizer Briquettes And Organic Manures On Yield, Nutrients Uptake And Chemical Properties Of Soil In Chilli (*Capsicum annuum* L.) In Lateritic Soils Of Konkan *Intl. J. of Agric. Sci. and Res.* 5 (2): 13-18

Kovacik, P. (2014). Principles and methods of plant nutrition. Nitra: SPU v Nitre (in Slovak) p:191

Kumar, A., Meena, R.N., Yadav, L. and Gilotia, Y.K. (2014). Effect of organic and inorganic sources of nutrient on yield, yield attributes and nutrient uptake of rice CV. PRH-10. *The bioscan.* 9(2): 595-597.

Li, X., J. Lu, L. Wu and F. Chen. (2009). The difference of potassium dynamics between yellowish red soil and yellow cinnamon soil under rapeseed145 (Brassica napus L.)–rice (*Oryza sativa* L.) rotation. *Plant Soil,* 320:141- 151.

Li, Y.F., Luo, A.C., Wei, X.H. and Yao, X.G. (2007). Genotypic variation of rice in phosphorus acquisition from iron phosphate. Contributions of root morphology and phosphorus uptake kinetics. *Russian J.*, 54(2): 230-236.

Lourduraj C.A., Yadav B.K., (2005). Effect of vermicompost application on soil and plant growth. Verms and vermitechnology. A.P.H. Publ. Cor. 5, Ansari Road, Darya Ganj, New Delhi. pp 81-96.

Lukman, S., Audu, A.M., Dikko, A.U., Ahmed, H.G., Sauwa, M. M., Haliru, M., Noma, S.S., Yusif1, S.A., Salisu, A. and Hayatu, N.G. (2016). Effects of NPK and Cow Dung on the Performance of Rice (Oryza sativa) in the Sudan Savanna Agro-ecological Zone of Nigeria. *Asian Res. J. Agric*., 1(4): 1-9.

Mahmud, A.M., Shamsuddoha,A.T.M., Issak,M. Haque M.N. and Achakzai, A.K.K. (2016). Effect of Vermicompost and Chemical Fertilizer on the Nutrient Content in Rice Grain, Straw and Post Harvest Soil. *Middle-East J. Sci. Res*., 24 (2): 437-444

Manzoor, Z., Awan, T.H.,Safdar,M.E., Ali, R.I.,Ashraf, M.M. and Ahmad, M.(2006). Nitrogen effect on yield components of basmati. *J. Agric. Res.* 44(2):122.

Maryam, J.M. and Ebrahim, A. (2014). Effect of nitrogen and potassium on yield and yield components of rice cultivar "HASHEMI". Department of Agriculture, Lahijan Branch, Islamic Azad University, Lahijan, Iran. *Indian J. of Fundamental and App. Life Sci.*, 4(4):417-424

Mathew, T. and Nair, S.S. (1997). Physical and chemical properties of rice soils as influenced by organic and inorganic sources of nutrients. *Indian J. Agril. Res.,* 31(4): 257-261.

Medhi, B.D., Barthakur, H.P. and Barthakur, S.N. (1996). Effect of organic and inorganic source of N on the nutrient in soil and soil solution and growth of rice. *J. Indian Soc. Soil Sci*., 44(2): 263-266.

Meelu, O.P., Morris, R.A., Furoc, R.E., and Dizon, M.A. (1992). Grain yield response in rice to eight tropical green manure. *Trop. Agric. (Trinidad*). 68: 133-136.

Meena, K.C. (2003). Vermiculture in relation to organic farming. *Intensive Indian Farming*, 41(8): 11.

Meena, S.L.,S. Singh and Y.S. Shivay. (2002). Response of hybrid rice (Oryzasativa) to nitrogen and potassium application. Division of Agronomy, Indian Agricultul'al Research Institute, New Delhi. *Indian J. Agron*., 47(2):207-211.

Mendoza, (2004). Organic/sustainable agriculture : case studies in the Philippines (Rice based farm system in Infanta, Queazon). www.organicrice.casestudy.html.

Misra, C., B.C. Mohanty, B.S. Das and N.K. Savant. (1995). Relationship between some selected soil properties and yield of transplanted rice fertilized with urea briquettes. oryza 32: 178–183

Mondal, S.S. and Swamy, S.N. (2003). Effect of time of N application on yield and yield attributes of rice (*Oryza sativa*) cultivars. *Env. Ecol*., 21(2): 411-413.

Mostofa, A., Raju, R.A. and Reddy, K.A. (2009). Response of rice (*Oryza sativa*) to nitrogen, phosphorus and potassium fertilizer on Godavari alluvia's. *Indian J. Agron*., 38(4): 637-638

Munujan, K., Hamid, A., Hashem, A., Hirota, O. and Khanam, M. (2001). Effect of nitrogen fertilizer levels and grain filling planting density on growth and yield of long grain rice. *Bull. Inst. Tropic. Agril. Kyushu. Univ.*, 24: 1-141.

Murali, M.K. and Setty, R.A., (2004), Effect of fertilizer, vermicompost and triacontanol on growth and yield of scented rice. Oryza, 41 (1&2): 57-59.

Murthy, K.M.D., Rao, A.U., Vijay, D. and Sridhar, T.V. (2015). Effect of levels of nitrogen, phosphorus and potassium on performance of rice. *Indian J. Agric. Res*., 49(1): 83-87.

Nadaf, A.B., Krishnan, S. and Wakte, K., 2006, Histochemical and biochemical analysis of major aroma compound (2-acetyl-1- 1pyroline) in basmati and other scented rice (*Oryza sativa* L.). *Curr. Sci*., 91: 11-14.

Nahar, K., Haider, J. and Karim, A.J.M.S. (1995). Residual effect of organic manure and influence of nitrogen fertilizer on soil properties and performance of wheat. *Annals Bangladesh Agric*., 5(2): 73-78.

Nair, C.S. and Rajasree, B. (2004). Efficiency of phosphate concentrate (34/74) and super phosphate at two levels on yield characters of rice in the neutral to alkaline soils of Chittoor palaghat Kerala. *Indian J. Agron.*, 46(3): 98- 104

Nambiar, K.K.M. (1997). Nutrient management for soil fertility restoration and sustaining cropping system productivity. In Nutrient Management Practices in Crops and Cropping System. *Sci. Pub., India*. pp. 213-250.

Natarajan, S., Ganapfthy, M., Arivazhagan, K. and Manivannan, K. (2005). Effect of different levels of nitrogen and potassium on growth, nutrient uptake and yield of hybrid rice. *Indian J. Eco Biol*., 17(6): 593-595.

Naz, F., Ali, A., Iqbal, Z., Akhtar, N., Asghar S. and Ahmad, B. (2011) Effect of different levels of NPK fertilizers on the proximate composition of potato crop at Abbottabad. Sarhad J. Agric. 27(3): 353-356

Naznin, A., Afroz, H., Hoque, T.S. and Mian M.H. (2013). Effects of PU, USG and NPK briquette on nitrogen use efficiency and yield of BR22 rice. *J. Bangladesh Agril. Univ.* 11(2): 215-220.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of

Agronomy, *Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA*. p. 403-430.

Palm, C.A., Myers, R.J.K. and Nandwa, S.M. (1996). Combined use of organic and inorganic sources for soil fertility maintenance and replenishment. In: Replenishing soil fertility in Africa. *Proc. Int. Symp. Indianapolis*, USA, 6th Nov. 1996.

Peterson, J., (2007). Placement of nitrogen, phosphorus and potassium fertilizers by drilling in spring barley grown for malt without use of pesticide. *Plant and Soil Sci.* 57(1) 53-64

Prabha L.M. (2006). Vermitech– A potential technology for the conversion of wastes into biofertilizer Ph.D. Thesis Department of Biochemistry, Kongunadu Arts and Science College, Coimbatore, Tamil Nadu, India. pp. 79-86.

Prasad, N.K. and Kerketta, R. (1991). Soil fertility as influence by different cropping sequences. *Indian Agric. Sci*., 61:16-19.

Pulley, H.J., Beyrouty, C.A., Norman, R.J. and Shelly, N.A. (2000). Influence of nitrogen fertilizer timing and rate on rice growth. Research Series *Arkansas Agril. Expt. Station*., 476: 278-282.

Qiangsheng, W., Ruohong, Z., Yanfeng, D., Weixin C. and Pisheng, H. (2004). Effects of potassium fertilizer application rates on plant potassium accumulation and grain quality of japonica rice. *Sci. Agric. Sinica*., 37(10):1444-1450.

Rahman, M.M., Samanta, S.C., Rashid, M.H., Abuyusuf, M., Hassan M.Z. and Sukhi, K.F.N. (2016). Urea super granule and NPK briquette on growth and yield of different varieties of Aus rice in tidal ecosystem. *Asian J. Crop Sci.*, 8: 1-12.

Rajeev, K., Sandeep, K., Anil, K., Harnam, S. and Sanjeev, K. (2013). Effect of top dressing nitrogen and potassium on yield and yield component of rice *(Oryza sativa L). Agriways,* 1(2): 90-94.

Ramesh, P., Mohan Singh and Subba Rao A., (2005). Organic farming; its relevance to the Indian context. *Current Sci*., 88 (4): 561 -567

Ranjha, A.M. Waheed, S.M. Mehdi and S.S. Rehman (2001), Effect of Potassium Sources on Rice Yield, *Int. J. Agri. Biol*., 3(1): 69-71

Ravi, R. and Srivastava, O.P. (1997) Vermicompost a potential supplement to nitrogenous fertilizers in rice cultures. *Intl. Rice Res. Newsletter*, 22 : 30-31.

Roy, R., Bajpai, R.K., Bachkaiya, V., Roy, C.K., Joshi, K. and Sushma, S. (2019) Effect of Urea Briquettes in Combination of Organics on Root Growth and Nitrogen Losses in Rice Field. *Int.J.Curr.Microbiol.App.Sci* 8(1): 1463-1474.

Roy, R., Bajpai, R.K., Bachkaiya, V., Roy, C.K., Neha Padhi M.S. and Tirkey, A. (2018) Evaluation on Impact of Use of Urea Briquettes in Combination of Organics on Nutrient Use Efficiency in Irrigated Rice ,*Int.J.Curr.Microbiol.App.Sci* 7(12): 1464-1479

Sahrawat, K.L., Jones, M.P., Diatta, S. and Adam, A. (2001). Response of upland rice to fertilizer phosphorus and its residual value in an ultisol. *Communication in Soil Sci. and Plant Analysis*., 32(15-16): 2457-2468.

Sarkar, A.B.S., Kojims, N. and Amano, Y. (2001). Effect of nitrogen rates on Japonica and Indica rice under irrigated Ecosystem. *Bangladesh J. Sci. and Tech*., 3(1): 49-58.

Sarkar, S. and Singh, S.R. (1997). Integrated nutrient management in relation to soil fertility and yield sustainability under dry land farming. *Indian J. Agric. Sci*., 67(9): 431-433.

Sarkar, S. and Singh, S.R. (2002). Integrated nutrient management in relation to soil fertility and yield sustainability under dry land farming. *Indian J. Agric. Sci.* 84(1): 56-67.

Savant, N.K. and Stangel, P.J. (1990). Deep placement of urea super granules in transplanted rice: principles and practices. *Fertilizer Res.*, 25: 1 – 83.

Shah, A. L., Sarker, A. B. S., Islam, S. M. M. and Mridha, A. J. (2013). Deep placement of NPK briquette: Environment friendly technology for rice production. Paper presented at the National Workshop on deep placement of NPK briquette, held at BARC, Dhaka on March 28, 2013 in collaboration with IFDC.

Shrirame, M.D., Rajgire, H.J. and Rajgire, A.H. (2000). Effect of spacing and seedling number hill-1 on growth attributes and yield hybrids under low land condition. *Indian Soils and C.*. 10(1): 109-113.

Singh U, Patil K. S., Kapoor V., Deborah H., Kovach S. (2008). Improving crop yieldand fertilizer use efficiency with one- time nutrient deep placement. *Joint Annual meeting* 5-9: 675-717.

Singh, B. and Singh, Y. (2000). Potassium Nutrition of Rice-Wheat Cropping System. Department of Soils, Punjab Agricultural University, Ludhiana-141004, India. p (289-290).

Sudha B. and Chandini S. (2003). Vermicompost- a potential organic manure for rice. *Intensive Agric.*, 40:1-2.

Sudhakar, G., Christopher, Lourduraj, A., Rangasamy, A., Subbian, P. and Velayutham, A.. (2002). Effect of vermicompost application on the soil properties, nutrient availability, uptake and yield of rice- a review. *Agric. Review,* 23 (2): 127-133.

Sudhakar, P. (2016). Effect of Different Vermicomposts on the Yield, Nutrient Uptake and Nitrogen Use Efficiency in Sri Method of Rice Cultivation. *Intel. J. Tropical Agric.*34 (4): 885-888.

Sultana, M.S., Rahman, M.H., Rahman, M.S., Sultana, S. and Paul, A.K. (2015). Effect of integrated use of vermicompost, pressmud and urea on the nutrient content of grain and straw of rice (Hybrid Dhan Hira 2). *Intel J. Sci. and Res.* 5(11): 765-770.

Supriyadi, N.E. and Djumali D.D. (2017) The Influence of Granular and Briquette Compound Fertilizers on Growth, Productivity, and Sugar Content of Sugarcane, *Buletin Tanaman Tembakau, Serat & Minyak Industri*, Vol. 9(1):34−41

Tang, X., Shi, Y.M. and Hao, X. (2011). Phosphorus efficiency in a long term wheat–rice cropping system in China. *J. Agril. Sci*., 149(3): 297-304.

Tapkeer, P.B., Kasture, M.C. and Kadu J.B. (2017). Effect of different fertilizer briquettes on yield, nutrient uptake and soil fertility status of Dolichos bean (*Dolichos lablab* L.) in lateritic soils of Konkan. *Intl J. of Ch. Studies* 5(4): 367-371

Tharmaraj K, Ganesh P., Kolanjinathan K., Suresh Kumar R, and Anandan A. (2011). Influence of vermicompost and vermiwash on physico chemical properties of rice cultivated soil. *Curr. Bot.* 2(3): 18-21.

Upendrarao, A. and Srinivasalureddy, D., (2004). Integrated nitrogen management in low land rice. *J. of Res., Angrau,* 32 (2): 82- 84.

Vasanthi, D. and Kumaraswamy, K. (1999). Efficacy of vermicompost to improve soil fertility and rice yield. *J. Indian Soci. Soil Sci.,* 2 : 268-272.

Vasanthi, D. and Kumaraswamy, K. (1999). Efficacy of vermicompost to improve soil fertility and rice yield. *J. Indian Soci. Soil Sci.,* 2 : 268-272.

Vasanthi, D.A., Rajamannar, A. and Kumaraswamy, K. (1995). Influence of vermicompost on the yield and fertility status of the soil under rice-rice cropping systems. In : National Symposium on Organic Farming. Mahatma PhuleKrishiVidyapeeth, *College of Agric., Pune*, p.3.

Wang, W., Jian, L.U., Qing, Y., Xiao, K. and Hui, L. (2011). Effects of N, P, K fertilizer application on grain yield, quality, nutrient uptake and utilization of Rice. *Chinese J. Rice Sci*. 25(6): 645-653

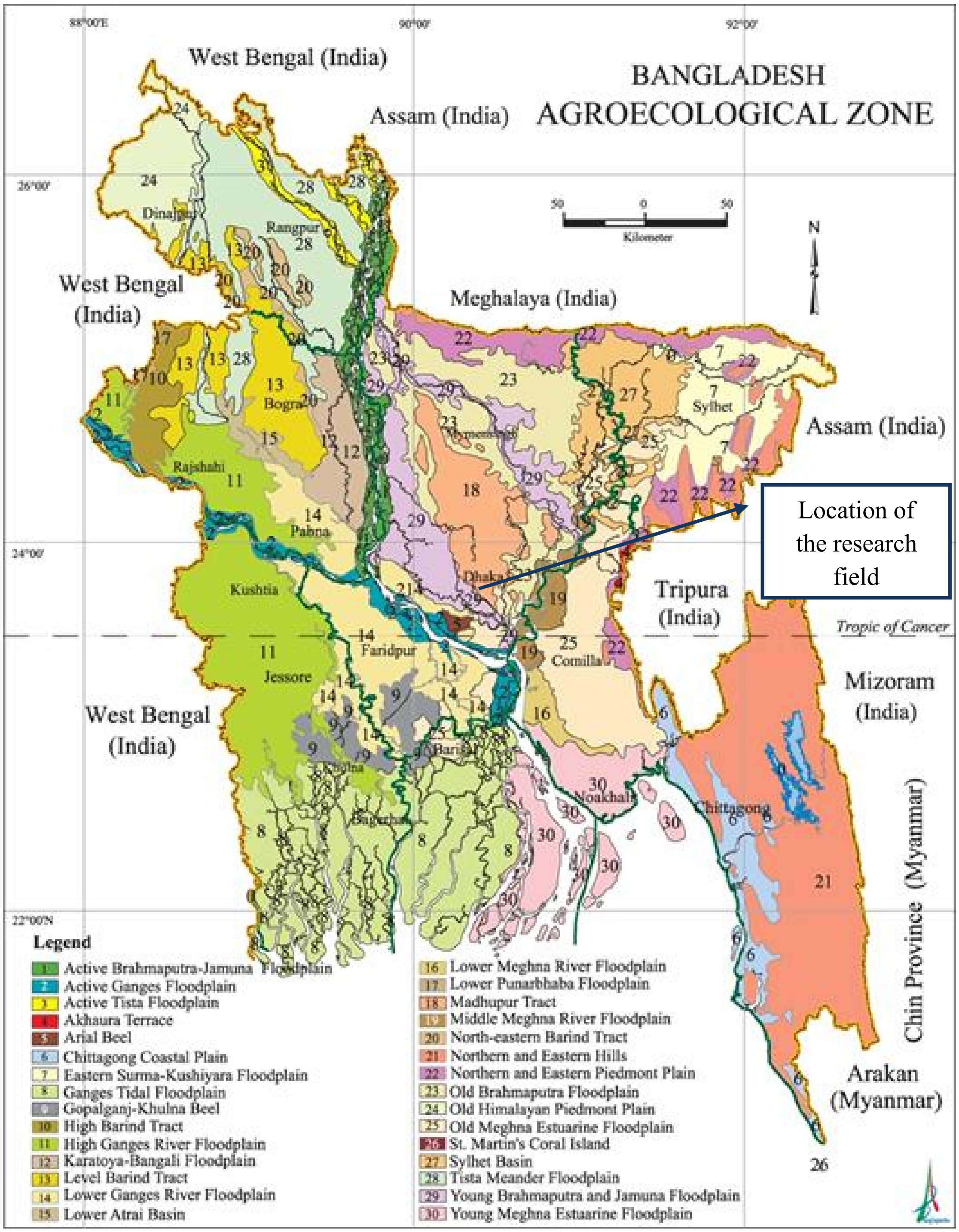
Xu, Y., Wang, Z., Li, Z., Guo, Y. and Wang, B. J. (1997). Methane productivity of two rice soils as affected by application of fertilizer. *Acta Agron. Sinica*., 232(2): 137-143.

Zaman, S., Hashem, M.A., Miah, M.H., Mallik, S.A. and Shamsuddoha, A.T.M. (2000). Effect of organic and inorganic sources of nitrogen and potassium on physical and chemical properties of soil under rice cropping. *Bangladesh J. Agril. Sci.*, 27(1): 71-76

APPENDICES

APPENDICES

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



Appendix II. Analysis of variance of the plant height of rice at different days after transplanting

Source of variation	Degrees of freedom	Mean Square							
		10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Replication	2	0.71	1.06	4.57*	7.94	10.81	11.4	8.25	14.67
Treatment	6	12.2**	19.1**	46.81 **	136.82 **	290.9 **	360.8 **	453.38 **	513.32 **
Error	12	1.99	2.19	3.65	5.7	6.2	6.1	7.2	9.5

* Significant at 5% level of probability
** Significant at 1% level of probability

Appendix III. Analysis of variance of the different attributes of rice

Source of variation	Degrees of freedom	Mean square					
		Total number of tiller per hill	Number of Effective tiller per hill	Number of ineffective tiller per hill	Days to panicle initiation	Panicle Length	Number of filled grains per panicle
Replication	2	4.1786	6.3957	0.10697	46.2857	2.1136	20.669
Treatment	6	46.2325**	78.8271**	4.47719**	40.9743**	2.5543**	45.16**
Error	12	1.9286	0.3457	0.04937	4.3249	0.4068	10.4276

* Significant at 5% level of probability
** Significant at 1% level of probability

Appendix IV. Analysis of variance of the different attributes of rice

Source of variation	Degrees of freedom	Mean square					
		Number of unfilled grains per panicle	1000 seed weight	Grain yield per hectare	Straw yield per hectare	Total Biological yield per hectare	Harvest Index
Replication	2	1.00000	0.34309	0.11063	0.11607	0.1354	2.05581
Treatment	6	1.99714**	2.54**	3.3382**	2.1271**	10.7041**	6.9608**
Error	12	1.02333	0.39442	0.05083	0.05357	0.0625	0.66619

* Significant at 5% level of probability
** Significant at 1% level of probability

Appendix V. Analysis of variance of the chemical properties of post-harvest soil

Source of variation	Degrees of freedom	Mean square				
		pH	Organic matter	Total N	Available P	Exchangeable K
Replication	**2**	5.0575	0.00413	7.00×10^{-06}	1.956	5.71×10^{-05}
Treatment	**6**	0.00384	0.0167**	7.81×10^{-04}**	164.835**	8.06×10^{-04}**
Error	**12**	0.1575	0.00173	7.00×10^{-06}	2.286	3.21×10^{-05}

* Significant at 5% level of probability
** Significant at 1% level of probability