EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON THE PERFORMANCE OF WET SEASON RICE

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON THE PERFORMANCE OF WET SEASON RICE**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE** embodies the result of a piece of *r*esearch work carried out by **EASRAT JAHAN TUMPA**, Registration No. **18-09187** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

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

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ABSTRACT

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh in Aman season during July to November 2019. The study was undertaken to investigate the effect of organic and inorganic fertilizers on the growth, yield, and yield components and to find out suitable combination of organic and inorganic fertilizers for achieving maximum yield of wet season rice. Eight nutrient combinations of organic and inorganic sources viz. T_1= No fertilizer (Control), T_2= N_{83} P_{15} K_{55} S_{10} Zn_1 kg ha^{-1} (Recommended fertilizers dose , T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung were tested against the high yielding rice variety BRRI dhan87 in wet season 2019. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Different organic and inorganic fertilizers significantly influenced the growth parameters, yield and yield components of BRRI dhan87. Among the nutrient management options, T_4 performed the best in respect of all of the parameters having growth, yield and yield contributing characteristics while the lowest value of those parameters was observed in the control treatment T_1. The longest plant height (128 cm) was recorded in T_4 followed by T_6 (120 cm) and the shortest plant (96 cm) being found in T_1 where the crop was not fertilized. The treatment T_4 produced the highest number of panicles $hill^{-1}$ (18.9) which was significantly higher than all other treatments. The highest number (97) of grains $panicle^{-1}$ were obtained in T_4 which was at par with T_6 (92), but significantly higher compared to the other treatments. Grain weight of BRRI dhan87 was also remarkably influenced by the nutrient management options and the highest 1000-grain weight (24.3 g) was obtained in T_4 that was at par with T6 (23.5 g) and T8 (23.4 g). Among the organic and inorganic fertilizers combinations, T_4 produced the highest grain yield (6.70 t ha^{-1}) which was statistically higher compared to all other treatments and the lowest grain yield (3.10 t ha^{-1}) obtained when the crop were not fertilized. Straw yield and harvest index followed the similar trend of grain yield. Moreover, mustard oil cake performed the best compared to poultry manure and Cowdung applied along with chemical fertilizers. Therefore, It could be concluded that the treatment T_4 (N_{83} P_{15} K_{55} S_{10} $Zn_{1kg\ ha}^{-1}$ + 75 kg ha^{-1} mustard oil cake) might be recommended for sustainable cultivation of wet season rice cv. BRRI dhan87 to obtained higher yield and better performance.

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ABBREVIATIONS AND ACRONYMS

N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
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

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is one of the most important staple cereal foods in human nutrition and major food grain for more than one third of the world's population (Karmakar, 2016; FAO, 2003). Rice is grown in more than a hundred countries with a total harvested area of nearly 163 million hectares, producing more than 755 million tons every year (FAO, 2020). In world, 90.6% rice is produced in Asian countries like China, India, Vietnam, Indonesia etc. (FAO, 2020). Rice is an excellent source of carbohydrates containing approximately 87 % in grain. It contains 7 to 8 % of protein, which has higher digestibility, biological value and more nutritious, possesses lower crude fiber and lower fat (1 to 2%). Nearly twenty percent of the world's dietary energy is provided by rice alone, which is higher than either wheat or maize (Sharada and Sujathamma, 2018). The human population is rapidly increasing and which needs a substantial increase in agricultural productivity worldwide. To feed the world population, productivity must be increased by 70% for an additional 2.3 billion people by 2050 (Tilman *et al.*, 2011).

Rice (*Oryza sativa*) is the most important cereal crop and the staple dietary item for the people in Bangladesh and the agriculture sector of the country is largely dominated by rice cultivation. Bangladesh is now the third largest global rice producing country (USDA, 2020). About 76% of the people live in rural areas, and 40.6% of the total manpower is involved in agriculture. In Bangladesh, agriculture contributes 14.23% of the gross domestic product (GDP) of the country (BBS, 2019). Bangladesh has a long history of rice cultivation. Rice is grown throughout the country except in the southeastern hilly areas. The agro climatic conditions of the country are suitable for growing rice year-round (Israt *et al.*, 2016). The total area and production of rice are about 11.8 million hectares and 35.30 million metric tons, respectively (FAO, 2020). Rice is cultivated in 71% of net cropped area in Bangladesh (USDA, 2020). The average yield of rice in Bangladesh is 4.53 ton per ha which is comparatively lower than those other South East Asian countries like China, Japan, Korea and Indonesia etc. (USDA, 2020). Due to ever-rising population, food security has become a key concern in Bangladesh. Consequently, maintenance of soil fertility is necessary for sustainable agriculture and future food security (Majumdar *et al*., 2016).

Among the rice producing countries of the world Bangladesh ranks the 3rd position produced 36 million metric ton (m. m. t.) clean rice while China and India producing 149 and 118 m. m. t. in 2020-21 year, respectively (Daily Sun, 2020). Recently, Bangladesh superseded Indonesia who produced 34.9 m. m t. clean rice in 2020-21. Rice is cultivating around 11.42 million ha including three seasons like Aus, Aman and Boro in Bangladesh from which Aman rice (wet season rice) is covering almost 51% land (BBS, 2018; Karmakar *et al,* 2021). However, yield of wet season rice is much lower compared to Boro season (Dry season rice). Consequently, there is enough scope to increase yield of wet season rice (Aman rice) through nutrient (organic and inorganic fertilizers) management.

Increasing cropping intensity, use of modern varieties (high yielding varieties and hybrids), cultivation of high biomass potential crops, nutrient leaching and unbalanced fertilizer application, with no or little addition of organic manure have resulted in nutrient mining from Bangladesh soils (BARC, 2018). To stop nutrient mining, it is not justified to increase the use of only inorganic fertilizers but the use of organic sources of plant nutrients viz. cow dung, mustard oil cake, poultry manure, compost, green manure should also be considered. Many farmers use higher amount of inorganic fertilizers while they seldom use organic fertilizers e.g. compost, mustard oil cake, poultry manure, cow dung. This practice creates imbalance use of fertilizers, which in turn produces a negative impact on crop production. The beneficial aspects of cow dung, mustard oil cake, poultry manure and compost in increasing crop growth and productivity and maintaining soil fertility have been proven. To increase the efficiency of manure and fertilizer in rice cultivation, it is necessary to identify the suitable combination of manure and fertilizer (Mitu *et al*., 2017). To achieve the higher yield of rice, inorganic fertilizers were used with little or no addition of organic manure. Even though the inorganic fertilizers were resulted in higher crop yield, over reliance on them associated with declined soil properties and degraded soils and in turn decreased yield in subsequent period (Hepperly *et al*., 2009). In the western world the present farming system totally depends on chemical fertilizers, growth regulators, pesticides for enhancing crop productivity. Several ill effects in human health and environmental hazards were documented due to the use of chemical fertilizer (Padmanabhan, 2013).

The most important and essential plant nutrient is nitrogen (N) and will increase the crop yield positively (Salman *et al*., 2012). N is required for all non-legume crops on all soil types. Nitrogen is supplied by indigenous sources such as soil minerals, soil organic matter, rice straw, manure, and water through rain or irrigation. In which crop residues are not returning to land nowadays due to intensive use as animal feed and fuel. Soil organic matter can only be replenished in the short term by the application of organic matter such as manures (Glaser *et al*., 2001).

Therefore, to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields (Rama Lakshmi *et al*., 2012). Organic matter is called the heart of soil and amendments of soil; by applying organic matter solely or in combination with inorganic fertilizers can be a biologically and economically viable approach to maximize rice yield sustainably along with a significant reduction in methane emission from rice fields (Swift, R.S. 1996; Baldock, J. A. and Nelson, P. N., 2000). Applying organic manure such as beef cattle feedlot manure that contains essential nutrients in addition to C for improving soil physical and chemical properties (Eghball, 2002). Application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone (Bokhtiar and Sakurai, 2005). The organic and inorganic fertilizer has helped to sustain soil fertility and crop productivity in rice (Nelson, P. N., 2000), mint and mustard cropping sequence with the use of farm yard manure (FYM), NPK and *Sesbania* green manuring (Chand, 2006).

Therefore, the present study was undertaken with the following objectives:

1. To investigate the effect of organic and inorganic fertilizers on the growth, yield, and yield components of wet season rice CV., BRRI dhan87.
2. To find out suitable combination of organic and inorganic fertilizers for maximum yield of BRRI dhan87.

CHAPTER 2

REVIEW OF LITERATURE

Growth and yield contributing characters of rice are considerably depends on manipulation of basic ingredients of crop production. The basic ingredients include variety, environment and agronomic practices (planting density, fertilizer, irrigation etc.). Among the factors nutrient management plays a key role for manipulation of the growth and yield of rice. High yielding varieties (HYV) are generally more adaptive to appropriate nutrient application. For getting more production both organic and inorganic fertilizers should applied in rice field with proper management. The available relevant reviews related to effect of organic and inorganic fertilizers on growth and yield of rice in the recent past have been presented and discussed under the following headings:

2.1 Effect of Inorganic Fertilizers:

2.1.1. Effect of Nitrogen fertilizer on Growth and Yield of Rice

Among the nutrients nitrogen (N) is very important for the production of modern varieties that are responsible for growth, yield and yield contributing characters of rice. N has a noble role on growth characteristics, yield and yield contributing components of rice through the process of photosynthesis, flowering to fruiting and maturity period (Nath, 2018). Nitrogen fertilizers has significant effect for boosting rice yields also recognized widely, particularly after the development of modern varieties. Nitrogen nutrient acts as a major part of protoplasm, protein and chlorophyll. It also plays a remarkable role in increasing cell size which in turn increases yield (Adhikari, 2018). For better grain development it is required to use adequate amount of nitrogen at early and mid-tillering and at panicle initiation stage (Awan, 2011). Excess or low nitrogenous fertilizer addresses some physiological problems which are prolonging growing period, lodging of plants, delayed in maturity, diseases and insect-pests susceptibility and ultimately reduces grain yield (Uddin, 2003).

A experiment conducted by Zhang *et al*. (2020) and the results showed that with the increase of nitrogen dose in a certain range, LAI, plant height, the number of tillers, net photosynthetic rate (NPn), the transpiration rate (Tr), and the grain yield increased while the lodging index (LI), the nitrogen agronomic utilization rate (AE) and nitrogen partial productivity (PFPN) decreased. Additionally, with the increase of nitrogen application, the grain yield index (HI) and nitrogen contribution rate (FCRN) of rice presented a parabolic trend.

Karim *et al.* (2019) conducted an experiment to observe the effect of urea fertilizer on the yield of two Boro rice varieties (BRRI dhan29 and BRRI dhan58). The result showed that plant height influenced due to urea application. Result also showed that longest panicle (21.4 cm), highest grain yield (6.7 t ha^{-1}) and straw yield (7.91 t ha^{-1}) were obtained by application of 300kg urea ha^{-1}.

Elhabet (2018) concluded that Nitrogen is one of constituent of chlorophyll and improves the activity of synthetase enzyme that increases the biosynthesis of chlorophyll. Nitrogen always increases the uptake of both phosphorus and potassium that enhance the nods and buds to emerge more tillers as a result to increase in cell division and elongation.

Haque and Haque (2016) conducted a field experiment to assess growth, yield and nitrogen use efficiency of a new rice variety. The new rice variety (BU dhan1) was treated with six levels of nitrogenous fertilizer viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1}. Results revealed that growth of the new rice variety favored at higher levels of applied nitrogen although it flattened at 80 and 100 kg N ha^{-1}. The highest grain yield (5.36 t ha^{-1}) was found when the variety was fertilized with 60 kg N ha^{-1}. Application of 60 kg N ha^{-1}also showed the highest nitrogen use efficiency (344.50 kg grain/kg N applied) of the variety.

Islam (2016) demonstrated a field experiment to study the effect of urea and NPK briquette on growth and yield of T. aman rice. The highest grain yield was found from the treatment of 52 Kg N ha-^{1} as one 1.8 g urea briquette/4 hills of rice.

Yesmin (2016) stated that applications of different forms of N significantly increased the yield components and grain and straw yields of BRRI dhan63. The performance of granular urea was superior to prilled urea. The treatment T_3 (1 USG in between 4 hills) produced the highest grain yield of 6.60 t/ha and straw yield of 7.43t/ha. The lowest grain yield 4.07t/ha and straw yield 4.53t/ha were found in control (T8: No nitrogen fertilizer) treatment.

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%.

Azarpour *et al*. (2014) conducted an experiment on growth and yield of three rice varieties (Khazar, Ali Kazemi and Hashemi) due to the effect of different nitrogen fertilizer. Results of growth analysis indicated that, nitrogen increasing rates of fertilizer caused the increment of growth indexes and yield of rice.

Rao *et al.* (2014) conducted an experiment during three consecutive kharif seasons with three rice varieties (RGL 2537, RGL 2332 and MTU 7029) and four nitrogen levels (60, 80,100 and 120 $kgha^{-1}$) with an objective to find out suitable variety with optimum nitrogen level for high altitude areas of Andhra Pradesh. Result showed that tiller production, days to 50 percent flowering, dry matter production at harvest, yield attributes, yields and harvest index, protein content of grain, soil organic carbon and available nitrogen were progressively augmented by incremental levels of nitrogen. Nutrient response in terms of partial factor productivity was progressively decreased with incremental levels of N from 60 kg to the highest dose tried. Post soil fertility status revealed that the status was progressively increased with incremental levels of N up to the highest dose that increased significantly by elevated levels of N.

Haque (2013) conducted an experiment to investigate the effect of five nitrogen levels viz. 0, 40, 80, 100 and 140 kg N ha^{-1} and he found the longest plant, highest number of total, effective tillers $hill^{-1}$, grains $panicle^{-1}$, grain and straw yields were observed with 100 kg N ha^{-1} followed by 140 kg N ha^{-1}.

Islam *et al*. (2013) concluded that, the highest grain yield (5.42 t ha^{-1}) and straw yield (6.38 t ha^{-1}) were obtained by application two pellets of USG (1.8g)/4 hills and three pellets of USG (2.7g)/4 hills.

Maqsood *et al*. (2013) reported that the nitrogen application at 100 kg N ha^{-1} provided a maximum paddy yield (4.39 and 4.67 t ha^{-1}) in both years. They also stated that higher paddy yield and yield components, as well as greater economic benefits, can be obtained at 100 kg N ha^{-1} nitrogen application.

Meng and Du (2013) showed that an appropriate nitrogen application rate could ensure that the rice canopy population reached a higher leaf area index (LAI). In addition, the formation of rice quality is also closely related to nitrogen.

Pramanik and Bera (2013) demonstrated an experiment during kharif season of 2010 and 2011 to investigate the optimization of nitrogen levels under different age of seedlings transplanted on growth, chlorophyll content, yield and economics of hybrid rice. Results revealed that among the nitrogen levels N200 kg ha^{-1} gave significant higher plant height, panicle initiation, number of tillers $hill^{-1}$, total chlorophyll content, panicle length and straw yield and nitrogen levels N150 kg ha^{-1} gave significant higher Number of effective $tillers^{-1}$, effective tiller index, panicle weight, filled grain $panicle^{-1}$, 1000 grain weight, grain yield, and harvest index as compared to N_0 (Control).

Xiang *et al.* (2013) demonstrated a field experiment to study the effect of deep placement of nitrogen fertilizer on growth, yield and nitrogen uptake of aerobic rice. They showed that urea and USG deep placement increased grain yield of aerobic rice by 1.66 t ha^{-1} and the soil significantly reduced nitrogen loss by ammonia volatilization.

Zhaowen Mo *et al*. (2013) reported that yield formation and growth of "super" rice (*Oryza sativa* L.) was affected by nitrogen application. The results showed that, N 187.5 kg ha^{-1} had the highest leaf area index (LAI) at full heading.

Dastan *et al*. (2012) reported that the maximum grain yield was observed for 150 kg ha^{-1} nitrogen application.

Hasanuzzaman *et al*. (2012) conducted an experiment on growth and yield of rice due to evaluate the effect of nitrogen fertilizer viz. 0, 80, 120, 160, 200 kg N ha^{-1}, USG @ 75 kg N ha^{-1}. Results indicated that N had a significant effect on effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ and 1000 grain weight. They also stated that application of nitrogen created significantly variation in grain yield, straw yield, biological yield and harvest index. USG gave the highest yield (9.42 t ha^{-1}) which was followed by 160 kg N ha^{-1} (8.58 t ha^{-1}). The increase in yield by the use of USG and 160 kg N ha^{-1} was 76.74% and 60.98%, respectively over control treatment (zero nitrogen).

Khorshidi *et al*. (2011) reported that the effect of nitrogen fertilizer had no significant difference on 1000 seeds weight and number of grains $panicle^{-1}$. The effect of fertilizers on rice yield showed that application of 100 kg of nitrogen had the highest yield of 5733 kg ha^{-1}. Data also indicated that yield had the highest positive correlation with panicle and harvest index.

Metwally *et al*. (2011) stated that grain and straw N contents were significantly affected by N treatment. Nitrogen content increased significantly affected by nitrogen fertilization and was the highest with 400 kg N ha^{-1}.

Kandil *et al*. (2010) found that the increasing nitrogen fertilizer levels up to 80 kg N ha^{-1} resulted in marked increases in number of tillers m^{-2}, panicle length, panicle weight, filled grains $panicles^{-1}$, 1000 grain weight, grain and straw yields ha^{-1} and harvest index in both seasons. They also stated that addition of 144 kg N ha^{-1} recorded the tallest plants and the highest number of panicles m^{-2}.

Artacho et al. (2009) reported that rice plants require nitrogen during their vegetative stage to prime growth and tillering, which will determine the potential number of panicles. In their study, they found an increase in rice yield, panicle density, spikelet sterility and dry matter production, in relation with increased N fertilization; these results are consistent with the findings by several other studies (Djaman et al., 2016; Fageria et al., 2011; Fageria and Baligar, 1999; Fageria and Baligar, 2001; Hirzel et al., 2011).

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

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

Rahman *et al.* (2005) experimented the different nitrogen level on rice and found that the grain yield of rice was increased with increasing nitrogen levels and the highest yield (4.19 t ha^{-1}) was attained with 150 kg N ha^{-1} while further increase in nitrogen level decreased the grain yield. It was estimated that the grain yield with 150 kg N ha^{-1}

was 35.8, 18.9, 5.0 and 6.0% higher than those obtained with 0, 50,100 and 200 kg N ha^{-1} respectively.

Chaturvedi (2004) report that the number of grain $panicle^{-1}$ against various applications of nitrogen fertilizers several that ammonium sulphate nitrate, produced maximum number of grains per panicle (95.2 and 95.9) during 2002 and 2003 respectively.

Chopra and Chopra (2004) showed that N had significant effects on yield attributes such as plant height, panicle $plant^{-1}$ and 1000 grain weight.

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

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

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

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

Ahmed *et al.* (2002) conducted an experiment and showed that among 5 levels, 80 kg N ha^{-1} gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Bayan and Kandasamy (2002) observed that effective tiller $hill^{-1}$ was significantly affected by the level of N and recommended doses of N (Urea) 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}.

Munnujan *et al*. (2001) conducted an experiment to find out the effect of nitrogen on rice yield and result showed 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* (Yumel vitachi) 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.

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 $hill^{-1}$.

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.

Rajarathinam and Balasubramaniyan (1999) indicated that there was no appreciable change in grains $panicle^{-1}$ due to higher dose of N above 150 kg ha^{-1}. They also noticed an appreciable reduction in grains $panicle^{-1}$ at 250 kg N ha^{-1}.

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

2.1.2. Effect of Phosphorus on Growth and Yield of Rice

Phosphorus deficit is a most important restrictive factor in plant growth and recognition of mechanisms that increase plant phosphorus use efficiency is important (Alinajoatisisie & Mirshekari, 2011). Phosphorus is a major component in ATP, the molecule that provides ”energy” to that plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material DNA, RNA (Wilson *et al.*, 2006). Phosphorus application to rice increased P accumulation but did not consistently increase rice yields because flooding decreased soil P sorption and increased P diffusion (Delong *et al.*, 2002).

Imrul *et al.* (2016) carried out a field to investigate the influence of nitrogen and phosphorus on the growth and yield of BRRI dhan57. Four levels of nitrogen N_0: 0 kg N ha^{-1}, N_1: 90 kg N ha^{-1}, N_2: 120 kg N ha^{-1}, N_3: 150 kg N $ha^{-1}$and three levels of phosphorous P_0: 0 kg P_2O_5 ha^{-1}, P_1: 25 kg P_2O_5 $ha^{-1}$and P_2: 35 kg P_2O_5 ha^{-1}were used in this experiment. Results revealed that the highest 1000 grain weight (20.85 g), grain yield (4.95 t ha^{-1}), straw yield (5.39 t ha^{-1}) and biological yield (10.34 t ha^{-1}) were found in the treatment combination N_2P_2 and also found highest in each individual under N_2 and P_2 treatments.

An experiment was conducted by Uddin *et al*. (2015) to on the performance study of rice regarding to growth, yield and yield contributing characters of rice BRRI dhan57 under the AEZ-28. The result obtained from the study, it was found that all the traits were statistically significant due to Phosphorus whereas 40 kg P $ha^{–1}$ recorded the tallest plant (109.70 cm) at harvest and maximum tillers $hill^{–1}$ (17.58) at 85 DAT. 40 kg P $ha^{–1}$ also recorded the greater results on effective tillers $hill^{–1}$ (13.67), panicle length (22.04 cm), filled grains $panicle^{–1}$ (138.60), 1000-grain weight (30.75 g), weight of grain, straw and biological yield 5.12, 8.39 and 13.51 t $ha^{–1}$, respectively and harvest index (37.85%) at harvest while without phosphorus obtained the lower results on the above.

A field experiment was conducted by Kabir (2014) to study the performance of BRRI dhan56 regarding to growth, yield and yield contributing characters under the AEZ-28. Experiment concluded that all the traits were statistically significant due to phosphorus whereas the tallest plant (109.70 cm) and maximum tillers $hill^{–1}$ (15.99) was found in treatment P_2 (40 kg P ha^{-1}) at harvest. Treatment P_2 (40 kg P ha^{-1}) also recorded the maximum results on effective tillers $hill^{-1}$ (13.67), filled grains $panicle^{-1}$ (138.60), 1000 grain weight (26.73 g), grain, straw and biological yield (5.12, 8.39 and 13.51 t ha^{-1} , respectively) and harvest index (37.85%) at harvest while P_0 (control) obtained the minimum results on the above traits (7.98, 110.0, 22.83 g, 3.77 t ha^{-1} , 7.05 t ha^{-1} , 10.82 t ha^{-1} and 34.82%, respectively).

A field experiment was conducted by Srivastava *et al.* (2014) on basmati rice wheat rotation with five different phosphorus levels viz. 0, 8.7, 17.5 and 26.2 kg P ha^{-1}. The highest pooled grain yields of basmati rice was obtained with soil application of 17.5 kg P ha^{-1}.

Yosef Tabar (2012) demonstrated and experiment in order to investigate the effect of nitrogen and phosphorus fertilizer on spikelet structure and yield in rice (*Oryza sativa*). He used phosphorus fertilizer at 4 level 0 (control), 30, 60 and 90 kg ha^{-1}. Results revealed that increasing the level of phosphorus up to 26.4 kg ha^{-1} also significantly increased the number of spikelets $panicle^{-1}$. Application of phosphorus increases the total number of spikelets $panicle^{-1}$ in rice thereby contributing to increment in grain yield. Maximum grain and biological yield was (44.70) and (91.20) respectively that observed for 90 kg ha^{-1} phosphorus fertilizer and minimum of these was (36.50) and (76.38) respectively obtained for (control) 0 kg ha^{-1} phosphorus fertilizer. Maximum harvest index was 47.92 observed for 90 kg ha^{-1} phosphorus fertilizer and minimum of that were 47.79 obtained for (control) 0 kg P ha^{-1}.

Panhawar *et al*. (2011) Phosphorus is important for plant growth and promotes root development, tillering and early flowering and performs other functions like metabolic activities, particularly in synthesis of protein. He also stated that phosphorus fertilizer application has been reported to increase upland rice yield.

Tang *et al.* (2011) conducted a field experiment 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. They suggested that, the P fertilizer utilization efficiency should be considered when making P fertilizer recommendations in wheat–rice cropping systems to achieve higher crop yields.

Yosefi *et al*. (2011) reveals that grain number per panicle was significantly influenced by phosphorus fertilizer.

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. Experiment concluded that application of 10 kg P ha^{-1} significantly increased the grain yield but when 20 and 30 kg P ha^{-1} applied the grain yield difference was not significant. They also stated that for T. Aman optimum and economic rate of P 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 phosphorus balance was observed up to 10 kg P ha^{-1}.

Alam *et al*. (2009) conducted a field experiment to study the relative performance of inbred and hybrid rice varieties at different levels of Phosphorus (P). Results revealed that Phosphorus at 72 kg ha^{-1} produced the highest grain yield (7.23 t ha^{-1}) of rice. Plants grown without added P gave the lowest grain yield (4.99 t ha^{-1}).

Wilson *et al.* (2006) reported that phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material DNA, RNA.

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^{-1} 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.

Salton *et al.* (1999) reported that rice yield varied with soil test levels of P & K but not significantly affected by P & K fertilizers.

2.1.3. Effect of Potassium on Growth and Yield of Rice

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).

Maryam and Ebrahim (2014) conducted an experiment to investigate the effect of nitrogen and potassium fertilizers on yield and yield components of a rice cultivar "Hashemi". The results 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 fertilizer level of 90 kg ha^{-1} possessed the highest yield (5714 kg ha^{-1}). The highest number of tiller (526.7 tillers per m^{-2}) obtained at the fertilizer level of 90 kg ha^{-1} nitrogen with and 150 kg ha^{-1} potassium. 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.

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. Results showed that the yield contributing characters like plant height, tiller number, and dry matter yield were the highest in 100 kg ha^{-1} of K.

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

Diba *et al*. (2005) reported a positive effect of K fertilizer use on rice yield contributing parameters.

Bijay Singh *et al.* (2004) stated that potassium (K) removal by rice wheat cropping system in the Indo-Gangetic Plains and in China ranges from 132 to 324 kg ha^{-1} in dependence from the cropping system and the productivity. They also stated that long-term on-farm experiments conducted in different Asian countries indicated that initial rice yield increase due to K application was not significant.

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

Meena *et al.* (2002) stated that 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.

BRRI (2001) reported that over 16 year period, the omission of potassium (K) fertilizer significantly decreased the yield of rice and the yield gap between the balanced treatment and the zero K treatment widen sharply with time.

Saleque *et al*. (1998) conducted on six farm trials on K deficient Barind soil of Bangladesh to evaluate the response of rice to K fertilizers & observed that application of 30 kg ha^{-1} significantly increased grain yield at all the test locations. They also reported that K application increase K content only in the straw but not the grain.

Ahsan *et al.* (1997) stated that a negative K balance even up to 60 kg ha^{-1} applied K level with diminishing magnitude was observed in a recent study of BRRI and suggested that an amount of about 60 kg ha^{-1} K would be required to sustain soil native potassium for rice cropping. Recent study indicated that about 60% cultivable land of Bangladesh is deficient in N, P and K. Most of the area of the North Western part of the country is deficient in K.

Tiwari (1985) reported that the potassium (K) reserve of any soil is certainly limited, and no soil can supply potassium to crops adequately for an indefinite period of time. Some studies on K buffering capacity, K depletion, K release pattern and relationships of some soils indicated that there is a difference in soils in immediate and long term availability of potassium (K).

2.1.4. Effect of Zinc on Growth and Yield of Rice

Zinc is one of the most important micronutrient essential for plant growth especially for rice grown under submerged condition. Zinc is required in a large number of enzymes and plays an essential role in DNA transcription. To give impetus to the vegetative growth zinc plays a vital role especially under low temperature ambient and rhizosphere regime. Adequate availability of zinc to young and developing plants is certain promise for sufficient growth and development (Singh *et al.* 2012). Zn deficiency is the most widespread micronutrient disorder in lowland rice and application of Zn along with NPK fertilizer increases the grain yield dramatically in most cases (Fageria et al., 2011; Singh et al., 2011).

An experiment was conducted by Kamal *et al.* (2017) to see the effect of K, S and Zn application on the performance of growth, yield and yield contributing characters of BRRI dhan56 under the acidic soil in Sylhet region. Result revealed that all the characters except 1000 grain weight were affected significantly due to application of K, S and Zn. Results also showed that the treatment $K_{80}S_{12}Zn_{1.8}$ produced the highest plant height (100.40 cm), effective tillers hill^{-1} (8.13), longest panicle (27.87 cm) and grains panicle^{-1} (146.60), highest grain yield 4.38 t ha^{-1} and straw yield 6.03 t ha^{-1}.

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

Muthukumararaja and Sriramachandrasekhara (2012) reported that Zinc deficiency in flooded soil is impediment to obtain higher rice yield. Zinc deficiency is corrected by application of suitable zinc fertilizer. The results revealed that rice responded significantly to graded dose of zinc applied. The highest grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) was noticed at 5 mg Zn kg^{-1} which was about 100% and 86% greater than control (no zinc) respectively.

Singh *et al.* (2012) conducted a three year long experiment to study the effect of Sulphur and Zinc on Rice Performance and Nutrient Dynamics in Plants and Soil of Indo Gangetic Plains. Results revealed that rice plant height is significantly affected by sulphur and zinc. Tallest plant (101.7cm) was recorded at maturity with application of

6kg Zn ha^{-1}. Highest leaf area index LAI (4.29) at anthesis was produced in the plots treated with Zn at 6 kg ha^{-1}. Maximum rice yield (7.63 t ha^{-1}) was recorded with combined application of 30kg sulphur and 6kg zinc, whereas corresponding minimum rice yield (7.09 t ha^{-1}) was recorded with absolute control plots where no application of zinc and sulphur was done during entire experimentation period.

An experiment was carried out by Yadi *et al.* (2012) and they used three zinc fertilizer doses viz. 0, 20 and 40 kg ha^{-1}. The results showed that the most panicle number m^{-2} and harvest index had observed in 40 kg Zn ha^{-1} compared to control treatment. The highest zinc content in grain, zinc uptake in grain and straw, and nitrogen uptake in grain were observed in 40 kg Zn ha^{-1}, as the most zinc content in straw, nitrogen, potassium, phosphorus and sulphur content in grain and straw, and nitrogen uptake in straw were observed highest with application of 40 and 20 kg Zn ha^{-1}.

Mustafa *et al*. (2011) conducted a study to evaluate the effect of different methods and timing of zinc application on growth and yield of rice. Experiment was comprised of eight treatments viz., control, rice nursery root dipping in 0.5% Zn solution, $ZnSO_4$ application at the rate of 25 kg ha^{-1} as basal dose, foliar application of 0.5% Zn solution at 15, 30, 45, 60 and 75 days after transplanting. Maximum productive tillers per m^2 (249.80) were noted with basal application at the rate 25 kg ha^{-1} 21% $ZnSO_4$ and minimum (220.28) were recorded with foliar application at 60 DAT @ 0.5% Zn solution. They also stated that Zinc application methods and timing had significantly pronounced effect on paddy yield. Results showed that maximum paddy yield (5.21 t ha^{-1}) was achieved in treatment Zn (21% $ZnSO_4$) as basal application at the rate of 25 kg ha^{-1} and minimum paddy yield (4.17 t ha^{-1}) was noted in Zn (0.5% Zn solution) as foliar application at 75 DAT.

Khan *et al*. (2007) demonstrated a pot experiment to evaluate the effect of different levels of zinc application on the yield and growth components of rice at eight different soil series. Zn as $ZnSO_4.7H_2O$ (21%) was applied as 0, 5, 10 and 15kg ha^{-1} along with the basal doses of 120 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}. Experiment results showed that the increasing levels of Zn in these soil series significantly influenced yield and yield components of rice.

A study was carried out by Cheema *et al*. (2006) to evaluate the effect of four zinc levels on the growth and yield of coarse rice cv. IR-6. Four zinc levels viz., 2.5, 5.0, 7.5

and 10 kg $ZnSO_4$ ha^{-1} caused increase in yield and yield component as compared with control. Experiment concluded that final plant height, number of tillers $hill^{-1}$, panicle bearing tillers, number of primary and secondary spikelets, panicle size, 1000 grain weight, paddy and straw yield and harvest index showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

Raju and Reddy (2001) conducted field investigations to study the response of both hybrid and conventional rice to sulphur and zinc (10 kg ha^{-1}) applications and reported that zinc application failed to improve the yield markedly.

A field experiment was conducted by Ullah *et al*. (2001) to study the effect of zinc sulfate (0, 10, and 20 kg ha^{-1}) on rice variety BR30. Zinc sulfate, along with 60 kg P_2O_5 and 40 kg K_2O ha^{-1}, was incorporated during land preparation. 80 kg N ha^{-1} was applied by 3 equal installments during land preparation, and at 25 and 60 days after transplanting. Results showed that plant height; tiller number; 1000-grain weight; grain and straw yields; and grain, straw, and soil Zn contents increased with zinc sulfate application. The tallest plants (75.67 cm), the highest number of tillers (10.6 $hill^{-1}$), 1000 grain weight (28.70 g), the concentration of Zn in straw (101.93 ppm) and grain (73.33 ppm) were obtained with 20 kg zinc sulfate ha^{-1}.

Binod *et al*. (1998) conducted an experiment on rice (cv. Sita) was given soil application of 0, 12.5 and 25 kg $ZnSO_4$ ha^{-1}. After transplanting, plants were given soil applications of 0, 12.5 and 25 kg $ZnSO_4$ ha^{-1} and they obtained best results with application of 25 kg $ZnSO_4$ ha^{-1} to transplanted rice.

Mandal and Halder (1998) conducted a pot experiment using rice cv. BR11 with all combinations of 0, 4, 8 or 12 kg Zn ha-1 and 0, 5, or 20 kg S ha^{-1}. Addition of 8 kg Zn+ 20 kg S ha^{-1} gave the best performance in growth and yield of rice.

2.1.5. Effect of Sulphur on Growth and Yield of Rice

Sulphur (S) is involved in amino acid and protein synthesis, enzymatic and metabolic activities in plants, which account for approximately 90% of organic S in the plant (Singh *et al.* 2012). Its deficiency is fast emerging in areas under oilseeds and pulses due to higher removal of S by crops (Singh & Kumar, 2009). The sulphur requirement of rice varies according to the nitrogen supply. When S becomes limiting, addition of N does not change the yield or protein level of plants. Sulphur is required early in the growth of rice plants. If it is limiting during early growth, then tiller number and therefore final yield will be reduced (Blair & Lefroy, 1987).

An experiment was conducted by Uddin et al. (2015) to study the effect of sulphur on growth, yield and yield contributing characters of rice BRRI dhan57 under the AEZ-28. The result obtained from the study, it was found that 20 kg S ha^{-1} obtained the tallest plant (109.40 cm) at harvest and maximum tillers $hill^{-1}$ (16.28) at 85 DAT. The maximum effective tillers $hill^{-1}$ (12.12), longest panicle (21.35), higher weight of grain, straw and biological yield 4.75, 8.08 and 12.82 t ha^{-1}, respectively and harvest index (36.90%) were taken in 20 kg S ha^{-1} at harvest. It was also observed the minimum non effective tillers $hill^{-1}$ (2.83) and unfilled grains $panicle^{-1}$ (12.04) whereas all the Sulphur levels were produced statistically similar filled grains $panicle^{-1}$ and 1000 grain weight at harvest due to non-significant variation .

An experiment was carried out by Afroz *et al.* (2014) to study the effect of sulphur and boron on growth and yield of aman rice. Experiment concluded that the combined application of S and B significantly increased the number of effective tillers $hill^{-1}$, panicle length, grain and straw yields of rice. The highest number of effective tillers $hill^{-1}$, the highest panicle length and the highest grain and straw yields were found in 12 kg S + 1 kg B ha^{-1} treatment.

Kabir (2014) conducted An experiment at the Research Field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, during the period from July, 2013 to December, 2013 to study the performance of BRRI dhan56 regarding to growth, yield and yield contributing characters under the AEZ-28. Results revealed that all the traits were significant except plant height at 55DAT and filled grains $panicle^{-1}$ whereas 20 kg S ha^{-1} obtained the tallest plant (109.40 cm) at harvest and maximum tillers $hill^{-1}$ (14..75) at harvest. The maximum effective tillers $hill^{-1}$ (12.12), 1000 grain weight (27.52 g), grain, straw and biological yield (4.75, 8.08 and 12.83 t ha^{-1} , respectively) and harvest index (36.90%) were observed in S_2 (20 kg S ha^{-1}) at harvest.

Mondal (2014) conducted an experiment during the period from July to December, 2013 in T. Aman season in the experimental area Agronomy farm field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka AEZ No. 28 (The Modhupur Tract) to find out the influence of nitrogen and sulphur on yield of T. Aman rice (BRRI dhan34). In this experiment three different levels of sulphur 0, 8 and 12 kg S ha^{-1} used as treatment. Results showed that the longest plant (114.30 cm) was recorded from 8 kg S ha^{-1}.

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

Singh *et al.* (2012) conducted a three year long experiment to study the effect of Sulphur and Zinc on Rice Performance and Nutrient Dynamics in Plants and Soil of Indo Gangetic Plains. Results revealed that rice plant height is significantly affected by sulphur and zinc. Maximum rice yield (7.63 t/ha) was recorded with combined application of 30kg sulphur and 6kg zinc, whereas corresponding minimum rice yield (7.09 t/ha) was recorded with absolute control plots where no application of zinc and sulphur was done during entire experimentation period.

Jawahar and Vaiyapuri (2011) conducted a field experiment to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. The treatments comprised four levels of sulphur 0, 15, 30 and 45 kg ha^{-1} and silicon. Results showed that among the different levels of sulphur, sulphur at 45 kg ha^{-1} recorded higher values for yield (grain and straw) and nutrient uptake (NPKS) of rice, respectively.

Islam et al. (2009) conducted a field experiment to evaluate the effects of different rates and sources of sulphur on the yield, yield components, nutrient content and nutrient uptake of rice (cv. BRRI dhan30). They reported that the grain and straw yields as well as the other yield contributing characters like effective tillers $hill^{-1}$, panicle length, filled grains $panicle^{-1}$ and 1000 grain weight were significantly influenced due to application of sulphur. Results concluded that the highest grain yield of 5293 kg ha^{-1} and straw yield of 6380 kg ha^{-1} were obtained from 16 kg S ha^{-1} applied as gypsum. The lowest grain yield (4200 kg ha^{-1}) and straw yield (4963 kg ha^{-1}) were recorded with S control treatment. The application of sulphur significantly increased N, P, K and S uptake.

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

Mrinal and Sharma (2008) conducted a field trials during the rainy (kharif) season to study the relative efficiency of different sources (gypsum, elemental Sulphur and cosavet) and varying levels of sulphur (0, 10, 20, 30 and 40 kg S ha^{-1}) in rice. Results showed that the growth and yield attributing characters of rice increased with the sulphur application. The grain and straw yields of rice increased significantly with increasing levels of sulphur up to 30 kg S ha^{-1}. The difference between sulphur sources was generally not significant.

Bhuvaneswari *et al*. (2007) conducted a field experiment to study the effect of sulphur (S) at varying rates, i.e. 0, 20, 40 and 60 kg ha-1, with different organics, i.e. green manure, farmyard manure, press mud and lignite fly ash, each applied at 12.5 t ha^{-1}, on yield, S use efficiency and S optimization of rice cv. ADT 43. The results revealed that rice responded significantly to the application of S and organics compared to the control. The highest grain (5065 kg ha^{-1}) and straw yields (7524 kg ha^{-1}) was obtained with 40 kg S ha^{-1}.

Oo *et al*. (2007) demonstrated a field experiment to study the effect of N and S levels on the productivity and nutrient uptake of aromatic rice and concluded that aromatic rice requires 20 kg S ha^{-1} for increased productivity and uptake of N, P, K and S under transplanted puddle conditions.

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

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

Peng *et al.* (2002) conducted a field experiment and results showed that there was a different yield increasing efficiency with application S at the doses of 20-60 kg ha^{-1} to rice plant. The increasing rate of rice yield was 2.9-15.5% over control. A residual effect was also observed.

Xue *et al.* (2002) showed that due to Sulphur application rice yield increases ranged from 0.5 to 22.9% (average of 7.3%).

Raju and Reddy (2001) conducted field investigations to study the response of both hybrid and conventional rice to sulphur and zinc applications and reported significant improvement in grain yield was observed due to sulphur (20 kg ha^{-1}) application.

Tandon *et al.* (1995) observed that S application of 20 to 60 kg ha^{-1} significantly increased grain yield of rice and the average yield response due to S application was 17.1%. He also noted different sources of S were equally effective.

Haque & Jahiruddin (1994) studied the effect of single and multiple application S & Zn in a continuous rice cropping system and noted that crop yield were increased by S (20 kg ha^{-}1 as gypsum) & not generally by Zn.

2.2. Effect of Organic Fertilizers on Rice Production

Application of chemical fertilizers may increase its yield and using rate is rapidly increasing day by day. But the imbalanced and excess use of chemical fertilizers degrades the soil and the environment (Higa 1991). Among this condition, the use of organic amendments with inorganic fertilizers has long been recognized as an effective means of improving soil structure, enhancing soil fertility (Follet *et al*. 1981), increasing microbial diversity and populations (Barakan *et al*. 1995), microbial activity (Zink and Allen 1998), improving the moisture-holding capacity of soils and increasing crop yields.

2.2.1. Effect of mustard oil cake on Growth and Yield of Rice

Mustard seed contain about 24-40% oil, 17-26% protein and 19% hull. Mustard seeds are processed for oil extraction and the residue obtained is called mustard cake (Swati *et al*. 2015). Mustard oil cake supplies 5.1-5.2%, 1.8-1.9%, 1.1-1.3% N, P and K, respectively (BARC, 1997). It also supplies sufficient amount of S, Zn and B for the growth and yield of rice. Mustard oil cake has unique properties of organic ingredients that make it a favorable fertilizer and even herbicide source. Growers can get both fertilizer and pesticide benefits from mustard meals. It has been shown to control weeds, insect pests, nematodes and pathogens (Boydston *et al.* 2008; Vaughn *et al.* 2006; Norsworthy and Meehan 2005).

A field experiment was conducted by Alim (2012) to study the effect of different sources and doses of nitrogen application on the yield formation of Boro rice. Two *indica* modern Boro rice varieties (BRRI dhan28 and BRRI dhan36) and 21 nitrogen fertilizer combinations were used in the experiment. Results concluded that the application of 60 kg N ha^{-1} as urea with 60 kg N ha^{-1} as mustard oil cake (MOC) produced maximum grain and straw yield which was statistically similar to the yield of 50 kg N ha^{-1} as urea with 50 kg N ha^{-1} as MOC. The lowest values were found in control nitrogen application.

Randomized Complete Block Designed experiment having three replications was conducted by Sultana *et al*. (2008) at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh during *aman* season (July to December) of 2007 where mustard oil cake was tried at different levels (0, 25, 50, 75 and 100 kg ha^{-1}) and times (basal, 10 days after transplanting and 20 days after transplanting) with a high yielding fine rice variety BRRI dhan38. It was found that level of mustard oil cake and time of its application and their interaction exerted significant influence on all the characters of crop except panicle length and 1000 grain weight. Grain yields registered an increasing trend upto 75 kg ha^{-1} MOC. The highest grain yield (2.33 t ha^{-1}) was recorded from the MOC @ 75kg ha^{-1} applied at 10 DAT. Economic analysis showed that the highest net profit (Tk. 25421.7 ha^{-1}) and the highest benefit cost ratio (1.56) were recorded when MOC was applied @ 75 kg ha^{-1}. Therefore, application of MOC 75 kg ha^{-1} at 10 DAT appears to be the best for BRRI dhan38 from both yield and economic viewpoints.

Islam *et al.* (2007) was conducted a field experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Aman season, 2006 to find out the influence of mustard oil cake (MOC) on the performance of fine rice cv. Chinigura. The MOC was applied 0, 40, 80 and 120 kg ha^{-1} in three splits at basal, at 15 DAT and at 30 DAT. Experiment results showed that level of mustard oil cake significantly influenced the number of effective tillers $hill^{-1}$, grains $panicle^{-1}$, and grain and straw yields. The highest grain yield of 2.69 t ha^{-1} was obtained when 80 kg MOC ha^{-1} was applied, which was identical with the treatment of 120 kg MOC ha^{-1}. This could be due to the cumulative effect of highest number of effective tillers $hill^{-1}$, and number of grains $panicle^{-1}$. The lowest one (1.92 t ha^{-1}) was recorded, when no MOC was applied.

BRRI, (2004) reported that the highest grain yield of rice (7.06 t ha^{-1}), highest grains $panicle^{-1}$ (132) was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers.

Ali *et al*. (2001) recorded the highest rice grain yield from the combination of 50% N as MOC with 50% N as urea, and they also opined that like plant height, total tillers $hill^{-1}$, leaf area index (LAI), dry matter production and straw yield were influenced by MOC application.

2.2.2. Effect of Poultry manure on Growth and Yield of Rice

Ali *et al*. (2018) conducted a field experiment to investigate the influence of plant nutrient management on the yield performance of transplant *Aman* rice varieties. Results revealed that among the treatments, USG 1.8 g/4 hills and P, K, S, Zn + poultry manure 2.5 t ha^{-1} exhibited its superiority to other treatments in terms of plant height (131.0 cm), number of total tillers $hill^{-1}$ (10.67), number of effective tillers $hill^{-1}$ (9.13), grains $panicle^{-1}$ (92.71), 1000 grain weight (26.82), grain yield (6.0 t $ha^{-1)}$ and straw yield (8.35 t ha^{-1}).

A field experiment was conducted by Hoque *et al.* (2018) at two locations i.e. at Soil Science Field of Bangladesh Agricultural University and at Farmer's field of Fakirakanda village of Mymensingh Sadar to evaluate the effects of different organic fertilizers on the growth and yield of rice (BRRI dhan28). The experiments at each location containing seven treatments were laid out in a randomized complete block design with three replications. The treatments were T_0: Control, T_1: 75% RFD; T_2: 100% RFD, T_3: 75% RFD + Kazi Jaibo Shar (5 t ha^{-1}), T_4: 75% RFD + Kazi Jaibo Shar (3 t ha^{-1}), T_5: 75% RFD + Poultry manure (3 t ha^{-1}) and T6: 75% RFD + Cow dung (5 t ha^{-1}). They reported that application of poultry manure as well as Kazi Jaibo Shar showed positive effects on yield attributes, grain and straw yields of rice, nutrient (N, P, K and S) contents and uptake by grain, straw and in total. The performance of 75% RFD with 3 t ha^{-1} poultry manure was the best in producing yield components, grain and straw yields of rice.

A field experiment was conducted by Islam *et al.* (2018) at the Soil Science farm of Bangladesh Agricultural University, Mymensingh during the Aman season of 2011 for investigating the integrated effect of prilled urea (PU) and urea super granules (USG) with poultry manure (PM) on field water property, growth and yield of BRRI dhan49. There were seven treatments such asT_1: Control, T_2: 56 kg N ha^{-1} as USG; T_3: 83.5 kg N ha^{-1} as PU; T_4: 56 kg N ha^{-1} as USG+PM (3.0 t ha^{-1}); T_5: 83.5 kg N ha^{-1} as PU+PM (3.0 t ha^{-1}); T_6: 112.5 kg N ha^{-1} as USG; T_7: 165.0 kg N ha^{-1} as PU. They concluded that application of USG in combination with poultry manure produced NH4+-N slowly and steadily due to deep placement by keeping most of the urea nitrogen in the soil and out of the irrigation water. This resulted in continuous supply of available N throughout the growth period of rice plant, which ultimately gave the higher yield. The highest grain yield (5389 kg ha^{-1}) and straw yield (6921 kg ha^{-1}) was produced from T_4 (56 kg N ha^{-1} as USG+PM 3.0 t ha^{-1}).

A field experiment was conducted by Tazmin *et al.* (2015) to evaluate the effect of combined level of poultry manure and NPKS fertilizers on the performance of Boro rice. Results showed that the highest number of total tillers $hill^{-1}$ (14.90), number of non-effective tillers $hill^{-1}$ (4.328), panicle length (20.35), number of grains $panicle^{-1}$ (708.6), number of total spikelets (837.7), grain yield (4.64 t ha^{-1}) and straw yield (5.68 t ha^{-1}) were produced when the crop was fertilized with poultry manure at 2.5 t ha^{-1} with 75% NPKS.

Issaka *et al.* (2014) conducted a field experiment for three years to examine the effects of inorganic fertilizer (IF), poultry manure (PM) and their combinations on rice yield and possible residual effects. In 2011 SPAD values for IF and PM/ IF combinations (except 2.0 t ha^{-1} PM + 22.5-15-15 kg N: P_2O_5: K_2O ha^{-1}) were significantly higher in the sixth week onwards than PM. Number of panicles/plant and number of panicles m^2 were significantly higher for 90-60-60 kg N: P_2O_5: K_2O ha^{-1} and 2.0 t ha^{-1} PM + 22.5-15-15 kg N: P_2O_5: K_2O ha^{-1} than 6.0 and 4.0 t ha^{-1} PM resulting in significantly higher grain yield. Grain yield of IF was similar to grain yield of PM/IF combinations. In 2012 the residual effects showed a significantly higher SPAD value for the 6.0 t ha^{-1} PM. Also 6.0 t ha^{-1} PM, 4.0 t ha^{-1} PM and 4.0 t ha^{-1} PM + 30 kg N ha^{-1} had significantly high number of panicles $plant^{-1}$ and number of panicles m^{-2} than IF. Residual effect of PM applied at 4.0 t ha^{-1} and above gave significantly higher grain yield than IF. Mean grain yield for the three years showed that 4 t ha^{-1} PM + 30 kg N ha^{-1} and 2 t ha^{-1} PM + 22.5-15-15 kg N: P_2O_5: K_2O ha^{-1} gave significantly higher yields than the other treatments.

An experiment was conducted by Rouf (2014) in a net house of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from June to November 2013 in aman season to find out effect of fertilizer and manure on the nutrient availability and yield of T. Aman rice in different soil. BRRI dhan33 was used as the test crop in this experiment. The experiment comprised of two factors, Factor A: Soils from two different locations, S_1: SAU soil, S_2: Shingair soil (collected from Shingair Manikgonj) and Factor B: Levels of fertilizers and manures T_0: Control condition i.e. no fertilizers and manures; T_1: Recommended dose of fertilizer

($N_{120}P_{25}K_{60}S_{20}Zn_2$), T2: 50% NPKSZn + 5 ton cow dung ha^{-1}, T_3: 50% NPKSZn + 5 ton compost ha^{-1} and T_4: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}. Results revealed that the highest grain yield (123.65 g pot^{-1}) was found from T_4 (50% NPKSZn + 3.5 ton poultry manure ha^{-1}), while the lowest grain yield (33.70 g pot^{-1}) was obtained from T_0.

Fakhrul Islam *et al*. (2013) studied the fertilizer and manure effect on the growth, yield and nutrient concentration of BRRI dhan28 at Sher–e–Bangla Agricultural University research farm, Dhaka. The T5 (50% RDCF + 4 ton PM ha^{-1}) showed the highest effective tillers $hill^{-1}$, plant height, panicle length, 1000 grain wt., grain yield (5.92 kg $plot^{-1}$) and straw yield (5.91 kg $plot^{-1}$). The higher grain and straw yields were obtained organic manure plus inorganic fertilizers than full dose of chemical fertilizer and manure.

A field experiment was conducted by Rahman (2013) to study the effect of various organic manures and inorganic fertilizers with different water management on the growth and yield of Boro rice. BRRI dhan29 was used as the test crop in this experiment. 8 levels of fertilizer plus manure, as T_0: Control, T_1: 100% ($N_{120}P2_5K_{60}S_{20}Zn_2$) Recommended dose of Fertilizer, T2: 50% NPKSZn + 5 ton cowdung ha^{-1}, T_3: 70% NPKSZn + 3 ton cow-dung ha^{-1}, T_4: 50% NPKSZn + 5 ton compost ha^{-1}, T_5: 70% NPKSZn + 3 ton compost ha^{-1}, T_6: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and T_7: 70% NPKSZn + 2.1 ton poultry manure ha^{-1} were used in this experiment. Results showed that the highest grain yield (7.40 ton ha^{-1}) was found from T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-1}) treatment which was closely similar to T_6 (50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment and lowest yield was obtained from T_0 treatment.

Akter (2011) conducted an experiment and result revealed that the treatment T_4 (75% Urea + 25% N from poultry manure, 2.9 t ha^{-1}) produced the highest grain yield of 6334 kg ha^{-1} and straw yield of 8175 kg ha^{-1}. The lowest grain and straw yields (3112 and 3489 kg ha^{-1}, respectively) were found in control when no nitrogen was not applied from either fertilizers or manures Further, the treatment T_7 (100% Urea +2.0 t ha^{-1} poultry manure) performed better than T_2, T_3,T_5 and T_6 indicating the superiority of poultry manure over cow dung and compost. The N, P, K and S contents and uptake by BRRI dhan29 were profoundly influenced due to application of Urea in combination with cow dung, compost and poultry manure.

Hossaen *et al*. (2011) studied on the yield and yield attributes of *Boro* Rice due different organic manure and inorganic fertilizer. Results showed at 30, 50, 70, 90 DAT and at harvest stage the tallest plant (24.18, 31.34, 44.67, 67.05 and 89.00 cm) and the greatest number of total tiller hill^{-1} (5.43, 11.64, 21.01 and 17.90) at same DAT was recorded from T_5 (70% NPKS + 2.4 t PM ha^{-1}) and the lowest was observed from T_0 (control) in every aspect. The maximum number of effective tillers hill^{-1} (13.52), the longest panicle (24.59 cm), maximum number of total grain plant^{-1} (97.45), the highest weight of 1000 seeds (21.80 g), the maximum grain yield (7.30 t ha^{-1}) and straw yield (7.64 t ha^{-1}) was recorded from T_5 treatment compared to control (T_0).

Rashid *et al*. (2011) examine the effect of urea– nitrogen, cow dung, poultry manure and urban wastes on growth and yield of transplant *Boro* rice, cv. BRRI dhan29. Among the treatments, T_6 ($N_{50\%}$ + $PM_{50\%}$) produced 43.39% higher number of effective tiller hill^{-1} , maximum number of filled grains panicle^{-1} (121), highest weight of 1000 grains (29.30 g), maximum grain yield (5.54 t ha^{-1}) and maximum straw yield (5.89 t ha^{-1}) than control treatment. Application of 47.5 kg N along with 9.5 t poultry manure ha^{-1} produced the maximum panicle length (27.03 cm) with an increase of 18.03 percent over control treatment. The lowest number of filled grains panicle^{-1} (89), lowest weight of 1000 grains (21.17 g), lowest grain yield (3.06 t ha^{-1}) and the lowest straw yield (3.39 t ha^{-1}) was noted in control treatment.

Hasanuzzaman *et al*. (2010) conducted an experiment to observe the comparative performance of different organic manures and inorganic fertilizers on the growth and productivity of transplanted rice. The experiment comprises of 10 treatments viz. T_1 (Control), T_2 (Green manure @ 15 t ha^{-1}), T_3 (Green manure @ 15 t ha^{-1} + $N_{40}P_6K_{36}S_{10}$ i.e.50% NPK), T_4 (Poultry manure @ 4 t ha^{-1}), T_5 (Poultry manure @ 4 t ha^{-1} + $N_{40}P_6K_{36}S_{10}$ i.e. 50% NPK), T_6 (Cowdung @ 12 t ha^{-1}), T_7 (Cowdung @ 12 t ha^{-1} + $N_{40}P_6K_{36}S_{10}$ i.e. 50% NPK), T_8 (Vermicompost @ 8 t ha^{-1}), T_9 (Vermicompost @ 8 t ha^{-1} + $N_{40}P_6K_{36}S_{10}$ i.e. 50% NPK) and T_{10} ($N_{80}P_{12}K_{72}S_{10}$ i.e.100% NPK). They reported that plant characters, yield attributes and yield were significantly influenced by different treatments. Except plant height, total tiller per hills and biological yield all the parameters were found to be highest with the treatment T_5 (Poultry manure @ 4 t ha^{-1} + $N_{40}P_6K_{36}S_{10}$i.e. 50% NPK).

An experiment was conducted by Hossain *et al*. (2010) to study the effect of Urea, poultry manure (PM) and cowdung (CD) on the nutrient content and uptake by BRRI dhan29. They stated that application of poultry manure, cowdung and Urea significantly influenced the yield and yield components of BRRI dhan29 and N, P, K and S contents and uptake. The overall results indicate that application of PM 3 t ha^{-1} in combination with N 100 kg ha^{-1} can reduce the use of N fertilizer at a substantial level. The findings of the study suggest that integrated use of manure and fertilizer is more important for sustainable production of BRRI dhan29.

Nyalemegbe *et al*. (2010) found that combining 10 t ha^{-1} poultry manure with 60 kg N ha^{-1}, gave higher yields comparable to those under high levels of nitrogen application (i.e., 90 and 120 kg N ha^{-1}) applied solely.

Rahman *et al* (2009) conducted an experiment to evaluate the effect of Urea in combination with poultry manure and cow dung on BRRI dhan29. Experiment results showed that the application of manures and different doses of Urea fertilizers significantly increased the yield components and grain and straw yields of BRRI dhan29. The treatment receiving N 80 kg ha^{-1} and PM 3 t ha^{-1} produced the highest grain yield of 5567.29 kg ha^{-1} and straw yield of 6991.78 kg ha^{-1}.

Umanah *et al.* (2003) find out the effect of different rates of poultry manure on the growth, yield component and yield of upland rice cv. Faro 43 in Nigeria, during the 1997 and 1998 early crop production seasons. The treatments comprised 0, 10, 20 and 30 t/ha poultry manure. There were significant differences in plant height, internode length, tiller number, panicle number per stand, grain number/panicle, and dry grain yield. There was no significant difference among the treatments for 1000-grain weight.

Channbasavana and Biradar (2001) reported that the application of poultry manure @ 3 t ha^{-1} gave 26% and 19% higher grain yield than that of the control 1998 and 1999, respectively.

4.2.3. Effect of Cowdung on Growth and Yield 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 cow dung 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 cow dung 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.

A experiment was conducted by Muktadir (2014) to find out the response of urea and cow dung on two Boro rice varieties under wetland cultivation and result showed that tallest plant (101.40 cm), more effective tillers $hill^{-1}$ (23.90), longest panicle (33.14 cm), more grains $panicle^{-1}$ (219.30), highest 1000–grain weight (33.10 g), highest yield of grain, straw and biological (6.53, 7.96 and 14.49 t ha^{-1}) obtained by application of 3.84 ton cow dung ha^{-1} + 196.0 kg Urea ha^{-1} (V_2T_4) .

Sarkar (2014) found that the application of 75% RD of inorganic fertilizers + 50% cow dung showed superiority in terms of plant height (123.3 cm) and total tillers $hill^{-1}$ (13.87) where those were also highest in combination of BRRI dhan34 × 75% RD of inorganic fertilizers + 50% cow dung. Nutrient management of 75% RD of inorganic fertilizers + 50% cow dung (5 t $ha^{-1)}$ gave the highest grain yield (3.97 t ha^{-1}) and the lowest grain yield (2.87 t ha^{-1}) was found in control. The highest grain yield (4.18 t ha^{-1}) was found in BRRI dhan34 coupled with 75% RD of inorganic fertilizers + 50% cow dung and the lowest grain yield (2.7 t ha^{-1}) was found in BRRI dhan37 in control.

Rifat–E–Mahbuba (2013) found that the Application of N as PU, USG alone or in combination with cow dung significantly increased yield components, grain and straw yields of BRRI dhan28 rice. The treatment T_3 (78 kg N ha^{-1} from USG) produced the highest grain yield of 5.85 t ha^{-1} and straw yield of 5.50 t ha^{-1} due to the treatment T_6. The treatment T_2 (104 kg N ha^{-1} from USG) performed better than T_1 and T_4, indicating the superiority of USG over PU. The N, P and K uptake by BRRI dhan28 rice were influenced profoundly due to the application of USG alone or in combination with cow dung. The overall results indicate that application of USG in combination with cow dung could be considered more effective in rice production.

Hoshain (2010) conducted an experiment to investigate the effect of cow dung and nitrogen on rice cv. BRRI dhan50. He showed that highest number of effective tillers hill^{-1}, number of grain panicle^{-1}, grain yield ((6.13 t ha^{-1}) and biological yield were obtained from the combination of 6 t ha^{-1} cow dung with 120 kg N ha^{-1}.

Nyalemegbe *et al*. (2010) found that combining 10 t ha^{-1} of cow dung with 45 kg N ha^{-1} urea gave higher yields comparable to those under high levels of nitrogen application (i.e., 90 and 120 kg N ha^{-1}) applied solely.

Islam *et al*. (2008) showed that the highest plant height (109.49 cm), number of effective tillers hill^{-1} (9.43), number of total tiller hill^{-1} (13.33), grain yield (6.13 t ha^{-1}) and harvest index (46.04%) were obtained from the combination of 50% recommended fertilizer with 5 t ha^{-1} cow dung.

Aziz (2008) reported that effective tillers hill^{-1}, panicle length, 1000 grain weight and grain yield were highest in 15 t ha^{-1} cow dung application.

Lawal and Lawal (2002) conducted an experiment to evaluate the growth and yield of low land rice during rainy season in Nigeria to varying cow dung rates and placement method of fertilizer and showed that 1000 grain weight was significantly increased.

Saleque *et al.* (2004) showed that application of one third of recommended inorganic fertilizers with *5* t ha^{-1} Cowdung increased the low land rice yield than other treatments and gives yield 8.87t ha^{-1}.

Mannan *et al.* (2000) reported that manuring with cowdung (up to 10 t ha^{-1}) in addition to recommended inorganic fertilizers with late Nitrogen application improved grain and straw yield and quality of transplant aman rice over inorganic fertilizer alone.

2.3. Combined effects of Organic and Inorganic Fertilizers

Nyalemegbe *et al*. (2010) found that combining 10 t ha^{-1} of cow dung with 45 kg N ha^{-1}urea, or 10 t ha^{-1} poultry manure with 60 kg N ha^{-1}, gave yields comparable to those under high levels of nitrogen application (i.e., 90 and 120 kg N ha^{-1}) applied solely.

Buri *et al*. (2006) in an experiment with poultry manure, cattle manure, and rice husks, applied solely or in combination with mineral fertilizer (using urea or sulphate of ammonia as N source), found that a combination of a half rate of organic amendments and a half rate of mineral fertilizer significantly contributed to the growth and yield of rice.

Rahman (2001) reported that in rice-rice cropping pattern, the highest grain yield of Boro rice was obtained by NPKS and Zn fertilizer treatment while in T. Aman rice the 75% or 100% of NPKS Zn fertilizers + GM with or without cowdung gave the highest or a comparable yield. Application of cowdung along with NPKSZn resulted in markedly higher uptake of nutrient in Boro rice. In T. Aman rice application of NPKS (SIR) with GM and/or CD showed higher N, P, K, S and Zn uptake. The total N content and the available N, P, K, S and Zn status in soil increased slightly due to manuring. The whole results suggested that the integrated use of fertilizer with manure (*Sesbania,* cowdung) could be and efficient and practice for ensuring higher crop yields without degradation of soil fertility.

Islam (1995) found a significant yield increase with fertilizers with cowdung compared to N fertilizer alone in T. Aman rice. In the following rice, the yields with N fertilizer and residual of cowdung were higher than N fertilizer alone.

Gupta (1995) conducted field trial on different organic manure in India and reported that the application of field manure (10 t/ha) produced the highest grain yield (4.5 t/ha) followed by Poultry Manure (PM) and FYM which produced yield of 4.1 and 3.9 i/ha of rice grain respectively. The increase in rice yield with organic manure was 34-55% higher over control and 5-22% higher over NPK fertilizers.

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.

Nambiar (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.

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.

Maskina *et. al.* (1986) studied the effect of N application on wet land rice in a loamy sandy soil amended with cowdung (60 kg N ha^{-1}). The absence of urea cowdung/cattle manure increases the rice grain yield by 37%. Rice yield increased linearly with N rates whether or not the soil was amended with organic manure. Urea/N equivalent to cowdung and PM varied from 21-53 kg $ha^{-1}$and 50 to 123 kg ha^{-1}respectively.

CHAPTER 3

MATERIALS AND METHODS

This chapter includes the information regarding methodology that was used in execution of the experiment. A short description of location of the experimental site, climatic condition, materials and methods used in 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, Dhaka, Bangladesh in Aman season during July to November 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 Madhupur Tract", AEZ-28 (BARC, 2018). 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 area under the sub-tropical climate that is characterized by high temperature, high humidity and high 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 July to November 2019 have been presented in Appendix II. This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.3 Soil

The soil of the experimental field belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH was 6.7 and has 0.45 percent organic carbon. The land was above flood level and sufficient sunshine was available during the experimental period. Initial soil samples from 0-15 cm depths were collected from the experimental field. The physicochemical properties of the soil in the experimental field are presented in Table 1 and 2.

Table1. Morphological characteristics of the experimental field.

Morphology	**Characteristics**
General Soil Type	Shallow Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

Source: (BARC, 2018)

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)	6.7
Organic C (%)	0.45
Organic Matter (%)	1.17
Total N (%)	0.07
Available P (mg kg-1)	19.83
Exchangeable K (me 100 g^{-1})	0.131
Available S (mg kg-1)	14.45

3.3 Experimental Details

3.3.1 Planting Material

BRRI dhan87 is an early maturing highly productive monsoon rice variety suitable for Aman season, developed by the Bangladesh Rice Research Institute (BRRI). BRRI dhan87 which has been breed through a cross between BRRI dhan29 and a wild rice called *Oryza rufipogan* (IRGC103404). The variety was released in 2018 for cultivation in Aman season. Average grain yield and growth duration of BRRI dhan87 are 6.5 t ha^{-1} and 127 days, respectively.

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 8 different treatments combinations. Each block was subdivided into 8-unit plots and the treatments were randomly distributed to the unit plot in each block. Thus, the total number of unit plot was 24. The size of each plot was 3 m x 4 m and plots were separated from each other by levee (0.50 m).

There was 0.75 m drain between the blocks that separated the blocks from each other. There was 0.5 m border in all side of land. For better understanding the layout of the experiment has been presented in Figure 1.

Treatments:

There were eight treatments as follows:

T_1= Control (No fertilizer applied)

T_2= N_{83} P_{15} K_{55} S_{10} Zn_1 kg ha^{-1} (Recommended fertilizers dose, BRRI, 2020)

T_3= ½ T_2 + 75 kg ha^{-1} mustard oil cake (MOC)

T_4= T_2+ 75 kg ha^{-1} MOC

T_5= ½ T_2 + 3.7 t ha^{-1} Poultry manure (PM)

T_6= T_2 + 3.7 t ha^{-1} PM

T_7= ½ T_2 + 5 t ha^{-1} Cowdung

T_8= T_2 + 5 t ha^{-1} Cowdung

3.3 Crops establishment

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 soaked in water in a bucket for 24 hours. These were then taken out of water and incubated until emerged. The seeds started sprouting after 48 hours which were suitable for sowing within 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 1st week of July 2019 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design.

3.3.4 Fertilizers application

The fertilizers were applied as per treatments. No fertilizer was applied to the plot having T_1. T_2 was fertilized as per recommended fertilizer by BRRI as Nitrogen 83 kg, Phosphorus 15 kg, Potassium 55 kg, Sulphur 10 kg and Zinc 1kg. One third of urea and all the other inorganic and organic fertilizer were applied as basal dose. Rest urea was applied in two equal installments at tillering (20 days after transplanting-DAT) and panicle initiation stage (40 DAT).

3.3.5 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from nine 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-day-old seedlings of BRRI dhan87 were carefully uprooted from the seedbed and transplanted on 1August. Three seedlings $hill^{-1}$ were transplanted following 25 cm × 15 cm spacing. 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 plant growth period, two hand weeding were done at 20 and 40 DAT just after urea top dressing

3.3.8 Water management

The experimental plots were irrigated through irrigation channels. Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

3.3.9 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 @ 1.2 L ha^{-1}. 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 that considerable losses by pest should be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper was observed during tillering stage. But any bacterial and fungal disease was not observed. The flowering was uniform.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 07 November, 2019 when 80-90% of the grains were turned into ripening. 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 5 m^2 area. The grains were dried, cleaned and weighed for individual plot. The grain and straw weight were adjusted to a moisture content of 14% and 3% respectively and converted to t ha^{-1}.

3.5 Sampling and data collection

- Plant height (cm)
- Total no. of tiller per hill^{-1}
- Number of panicle hill^{-1}
- Panicle length (cm)
- Number of spikelets panicle^{-1}
- Number of filled spikelets panicle^{-1}
- Number of unfilled spikelets panicle^{-1}
- Grain and straw yield
- 1000 grain weight

Plant height

The height of plant was recorded in centimeter (cm) at maturity during the time of harvesting. 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 hill^{-1}

At maturity, tillers hill^{-1} were counted from 2 x 2 hill sampling units from three places (12 hills plot^{-1}) diagonally in each plot (Gomez, 1972). The sample hills were selected excluding border and harvest area. The sample hills were not hills that were replanted or adjacent to a missing hill.

Panicles hill^{-1}

At maturity, panicles hill^{-1} were counted from 2 x 2 hill sampling units from three places (12 hills plot^{-1}) diagonally in each plot (Gomez, 1972). The sample hills were selected excluding border and harvest area. The sample hills were not hills that were replanted or adjacent to a missing hill.

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.

Grains per panicle

The total numbers of grain was collected randomly from selected 10 plants of a plot on the basis of grain in the spikelet and then average numbers of grains per panicle was recorded.

Sterile spikelet panicle^{-1}

The total numbers of unfilled spikelet were 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 gram and recorded its moisture content. Weight of 1000-grains adjusted at 14% moisture content.

Grain and Straw yield

From the center of each plot, 5 m^2 area was harvested for determination of grain and straw yields at maturity. After harvest and threshing, grains were sun-dried, and weight and moisture content were measured. Grain yield was adjusted to 14% moisture content, and expressed in t ha^{-1}. Straw was also sun-dried and weighed. Subsamples from the straw were taken and oven-dried at 70^0C for 72 h and weighed. Oven-dried weight of straw was recorded. Straw yield was adjusted to 3% moisture content, and expressed in t ha^{-1}. Grain yield was calculated using the following formula (Karmakar, 2016):

$$\text{Grain yield (t ha}^{-1}\text{) at 14\% MC} = \frac{(100 - \%\text{M})}{86} \times \frac{\text{Grain wt (kg)}}{\text{Harvested area (m}^2\text{)}} \times \frac{10000}{1000}$$

Where,

MC = Moisture content

%M = % MC at weighing of grain

Grain wt. (kg) = Grain weight in kg at the time of weighing grain

Harvested area (m^2) = Sample harvested area in square meter for grain yield calculation.

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 computed as the ratio of grain yield and biological (grain + straw) yield (Karmakar and Sarkar, 2015) with the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield (Grain yield + Straw yield)}}$$

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$4 until the color changes from green to pink. The amount of N was calculated using the following formula:

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

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 (oven dried basis) 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).

3.6.5 Exchangeable potassium

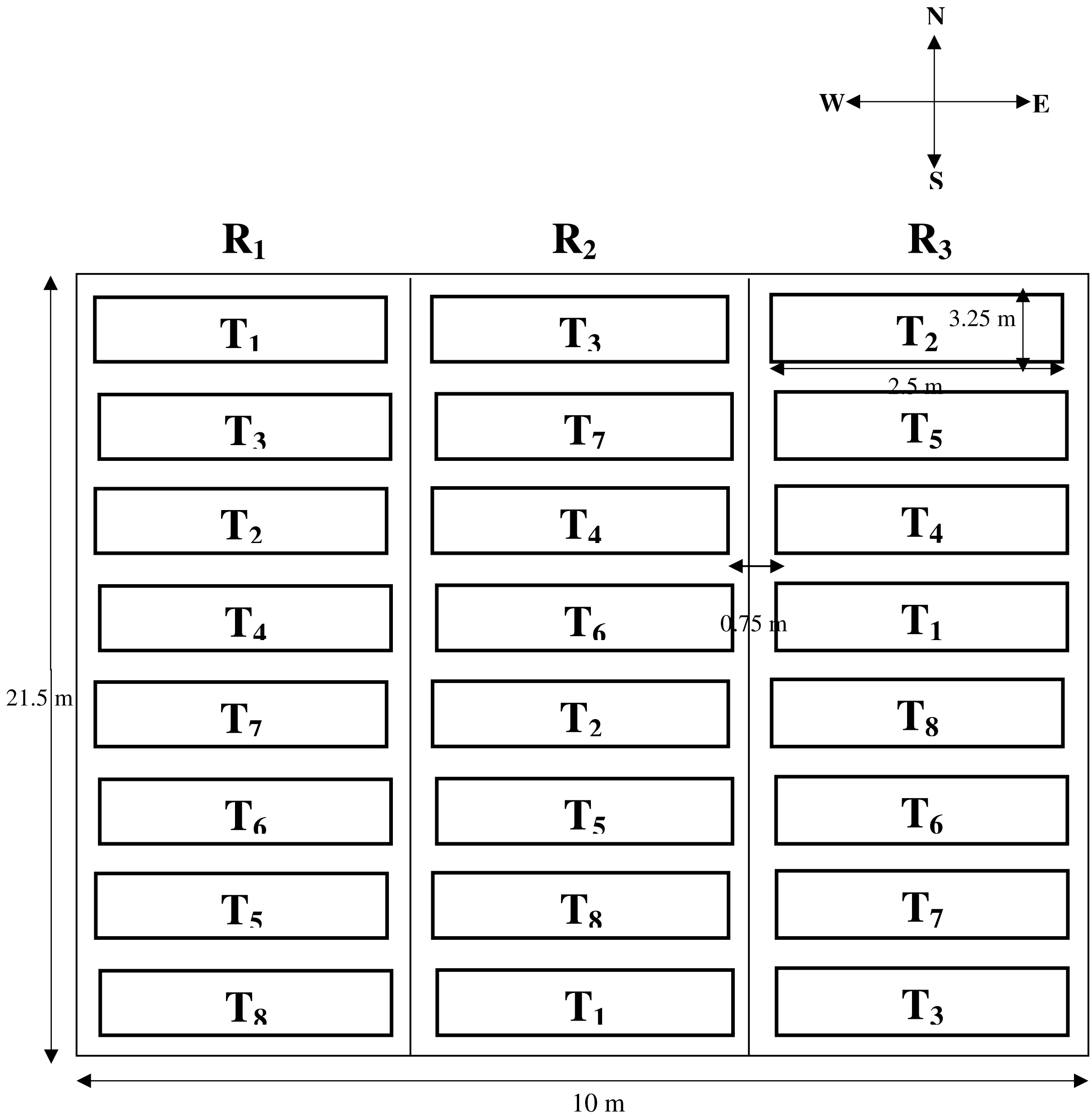
Exchangeable K in post-harvest soil was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*., 1982).

3.7 Statistical Analysis

The data obtained for different parameters were statistically analyzed and mean values of all the characters were calculated and analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using Statistics 10 computer software. The significance of the difference among the treatment means was compared using the Least Significant Difference (LSD) (Gomez and Gomez, 1984).

Field layout of the experiment

Total area	= 30m x 10m
One plot size	= 3.25 m x 2.5m
Block to block distance	= 0.75m
Plot to plot distance	= 0.50 m
Border	= 0.50 m
Total plot	= 24
Design	= Randomized complete block design



CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of organic and inorganic fertilizers on the growth and yield of BRRI dhan87. The results have been presented and discussed with the support of table and graphs and possible interpretations given under the following headings.

4.1 Plant height

Plant height significantly affected by the organic and inorganic fertilizers treatments (Figure 2). This findings are line with Karmakar, 2016. The tallest plant (128 cm) was recorded from T_4 followed by T_6 (120 cm). These results are in alignment with Sultana *et al*. (2008) who reported that application of mustard oil cake (MOC) 75 kg ha^{-1} at 10 DAT appears to be the best for BRRI dhan87 from both yield and economic point of view. The shortest plant (96 cm) was found in T_1 when the crop was not fertilized and it was significantly lower than all other treatments (Figure 2). Nutrient supply is important for plant height and nutrient supply is highest when both organic and inorganic fertilizers used with proper combination. The results showed that organic fertilizers have vital role to increase plant height especially the mustard oil cake along with chemical fertilizers. Chemical fertilizers supplies the adequate nutrients for plant growth whereas organic fertilizers supplies nutrient as well improve soil physical and chemical properties which creates a better environment for plant growth results in higher plant height. Similar results are also obtained by Alim (2012) and Islam *et al.* (2007). Ali *et al*. (2001) reported that plant height, total tillers $hill^{-1}$, leaf area index (LAI), dry matter production and straw yield were influenced by MOC application.

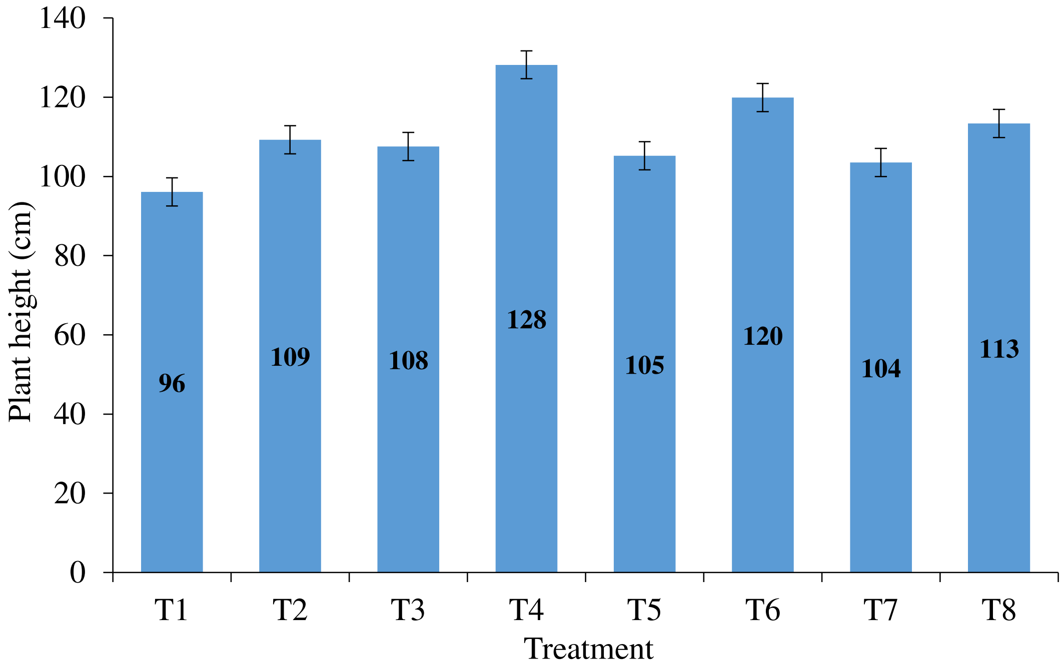


Figure 2. Effect of organic and inorganic fertilizers on plant height of BRRI dhan87

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

4.2 Number of tillers hill^{-1}

Number of tillers hill^{-1} of rice plants significantly differed among the different types of organic and inorganic fertilizer management practices (Figure 2). Data showed that maximum number of tillers hill^{-1} was found with T_4 (22.5) treatment. These results are similar with Ali *et al*. (2001). They reported that the combination of 75 kg ha^{-1} MOC with recommended N as urea influenced to attain higher number of tillers hill^{-1}, leaf area index (LAI), dry matter production and straw yield. This experiment also showed that the minimum number of tillers hill^{-1} was found in T_1 (14.5) (Figure 2). The higher number of tillers contributed for better vegetative growth and higher production. Nutrient supply is prerequisite for better vegetative growth which may result in higher number of tillers. Nutrient supply is highest when both organic and inorganic fertilizers used with proper combination. Similar results of this experiment are also obtained by Alim (2012), Sultana *et al*. (2008), and Islam *et al.* (2007).

4.3 Number of panicles hill^{-1}

The use of organic and inorganic fertilizers significantly influenced the number of panicles hill^{-1} of BRRI dhan87. Figure 2 shows the effects of different treatments on panicles hill^{-1}. The highest number of panicles hill^{-1} (18.9) was obtained in the T_4 treatment which was statistically significant compared to all other treatments. The second highest panicles hill^{-1} (16.4) was obtained in the T_6 treatment. The minimum number of panicles hill^{-1} (9.1) was obtained in the T_1 control treatment (figure 3). It was observed that the number of panicles per hill increased with the combination of organic and inorganic fertilizers. Islam *et al.* (2007) reported that mustard oil cake significantly influenced the number of effective tillers hill^{-1}, grains panicle^{-1}, and grain and straw yields. Alim (2012), Sultana *et al.* (2008), and Ali *et al.* (2001) supported that organic and inorganic fertilizer combination increase panicles hill^{-1} compared to recommended dose of inorganic fertilizers.

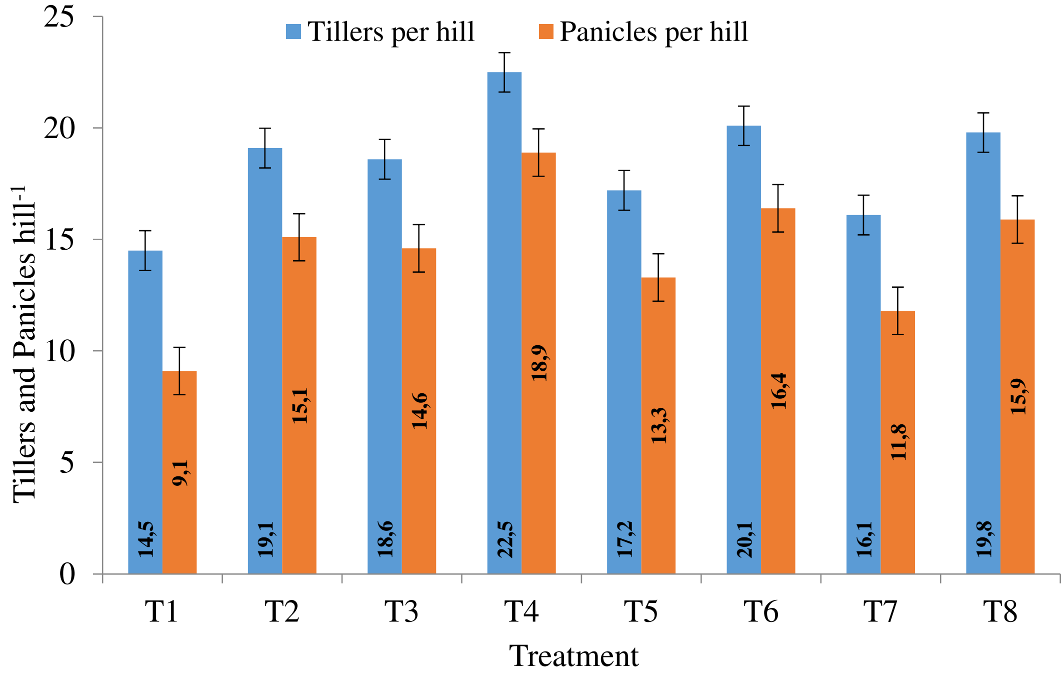


Figure 2. Effect of organic and inorganic fertilizers on number of tillers and panicle hill^{-1} of BRRI dhan87

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

4.4 Panicle length

Panicle length was significantly influenced by treatment combinations of organic and inorganic fertilizers. At harvest, the highest panicle length (32.8 cm) was obtained in the treatment T_4 which was statistically significant compared to all other treatments (Table 3). The 2nd highest panicle length (28.8 cm) was obtained in T_6 which showed no significant difference among with T_8. The lowest panicle length (20.1 cm) was obtained in T_1 (table 3). Alim (2012), and Ali *et al*. (2001) supported that organic and inorganic fertilizer combination increase panicle length of rice.

4.5 Number of spikelets panicle^{-1}

Table 3 showed the significant effect of organic and inorganic fertilizers on spikelets panicle^{-1} of BRRI dhan87. The highest number of spikelets panicle^{-1} (125.2) was obtained from T_4 treatment which was statistically similar with T_6 and T_8. The lowest number of spikelets panicle^{-1} (109.7) was obtained from T_1 (table 3). BRRI (2004) reported that the highest grain yield of rice (7.06 t ha^{-1}) contributed by the, highest spikelets panicle^{-1} (132) which was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers. Alim (2012), Sultana *et al*. (2008) and Ali *et al*. (2001) supported that organic and inorganic fertilizer combination increase number of spikelets panicle^{-1}.

4.6 Number of filled spikelets panicle^{-1}

Filled spikelets production of BRRI dhan87 was significantly affected by organic and inorganic fertilizers (Table 3). The highest number of filled spikelets panicle^{-1} (97.1) was obtained from T_4 treatment which was statistically similar with T_6 that was followed by T_6 (91.5) (Table 3). The lowest number of grains panicle^{-1} (71.1) was obtained from T_1. BRRI, (2004) reported that the highest grain yield of rice (7.06 t ha^{-1}), highest grains panicle panicle^{-1} (132) was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers. Similar views are reported by Sultana *et al*. (2008), Alim (2012) and Ali *et al*. (2001) who found that organic and inorganic fertilizer combination increase 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. Organic fertilizers like MOC, poultry manure, cowdung etc. also contain essential nutrients though in less amount but they also improve soil properties, increase the uptake of nutrient and water by the plant thus results in higher rate of photosynthesis (Hemalatha *et al.* 2000).

4.7 Number of unfilled spikelets panicle^{-1}

Table 3 showed the significant effect of organic and inorganic fertilizers on unfilled spikelets panicle^{-1} of BRRI dhan87. The highest number of unfilled spikelets panicle^{-1} (38.6) was obtained from T_1 treatment which was statistically similar with T_5 and T_7. The lowest number of unfilled spikelets panicle^{-1} (28.1) was obtained from T_4 which was statistically similar with $T_{2,}$ T_6 and T_8 (table 3). This study revealed that the plants produced the maximum no. of unfilled spikelets when they did not fertilized. Unavailability of nutrient is the main constrain to the spikelets 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 spikelets and thus produced higher number of unfilled spikelets. BRRI (2004) reported that the highest grain yield of rice (7.06 t ha^{-1}), highest grains panicle panicle^{-1} (132) was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers. Sultana *et al*. (2008), Alim (2012), and Ali *et al*. (2001) observed that organic and inorganic fertilizer combination decrease the number of unfilled spikelets panicle^{-1}.

4.8 1000-grain weight

Organic and inorganic fertilizers significantly influenced the grain weight of BRRI dhan87 (Karmakar, 2016). From the study we found that treatment T_4 produced the highest weight (24.3 g) of 1000-grain which is statistically similar T_6 (23.5 g) and T_8 (23.4 g) with and treatment T_1 produced the minimum Weight (21.5 g) of 1000-grain which was also statistically similar with T_8 (22.4 g) (Table 3). Maximum grain weight indicates the maximum grain yield. Results revealed that for maximum grain weight need proper amount of nutrient supply. Organic and inorganic fertilizers combination can supply proper amount of nutrient for rice plant. BRRI, (2004) reported that the highest grain yield of rice (7.06 t ha^{-1}), and the highest grains per panicle (132) was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers. Similar findings are also be reported by Sultana *et al*. (2008), and Ali *et al*. (2001).

Table 3. Effect of different fertilizer management treatments on rice related to yield & yield contributing characters

Treatments	Panicle length (cm)	Number of spikelets panicle^{-1}	Number of filled spikelets panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grains weight (g)
T_1	**20.1 f**	**109.7 d**	**71.1 e**	**38.6 a**	**21.5 c**
T_2	26.1 c	118.4 bc	86.5 bcd	31.9 cde	23.1 b
T_3	25.3 cd	116.6 bc	83.3 cd	33.2 bcd	22.9 b
T_4	**32.8 a**	**125.2 a**	**97.1 a**	**28.1 e**	**24.3 a**
T_5	24.4 de	116.5 bc	81.9 cd	**34.7 abc**	23.2 b
T_6	28.8 b	**121.5 ab**	**91.5 ab**	30.0 de	**23.5 ab**
T_7	23.4 e	114.8 cd	**78.9 de**	**35.9 ab**	22.4 bc
T_8	27.9 b	**120.0 abc**	89.1 bc	30.9 cde	**23.4 ab**
LSD $_{(0.05)}$	**1.69**	**6.57**	**7.99**	**3.94**	**1.12**
C. V. (%)	**3.69**	**3.18**	**5.38**	**6.83**	**4.50**

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

4.9. Grain yield (t/ha)

Combination of organic and inorganic fertilizers treatments showed significant differences on grain yield of BRRI dhan87. The experiment showed that among all treatment highest yield per hectare (6.70 t ha^{-1}) was obtained from T_4 (½ T_2 + 75kg mustard oil cake) treatment which was significantly higher than all other treatments. The lowest yield (3.10 t ha^{-1}) being recorded in T_1 (control) (Figure 4). BRRI, (2004) reported that the highest grain yield of rice (7.06 t ha^{-1}), highest grains panicle per panicle (132) was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers which was similar of this experiment findings. Experiment revealed that application of organic and inorganic fertilizer gives highest yield per hectare. Adequate amount of nutrient availability of nutrients in soil increase the number of effective tillers, panicle number and filled grain which helps to increase the total yield of rice. This experiment revealed that highest grain yield of BRRI dhan87 was obtained by the application of 75 kg mustard oil cake with proper combination of inorganic fertilizers. Islam *et al.* (2007) reported that the level of mustard oil cake significantly influenced the number of effective tillers $hill^{-1}$, grains $panicle^{-1}$, and grain and straw yields. They also concluded that the highest grain yield of 2.69 t ha^{-1} was obtained when 80 kg MOC ha^{-1} was applied, which was identical with the treatment of 120 kg MOC ha^{-1}. Sultana *et al*. (2008), Alim (2012) and Ali *et al*. (2001) supported the findings of this experiment.

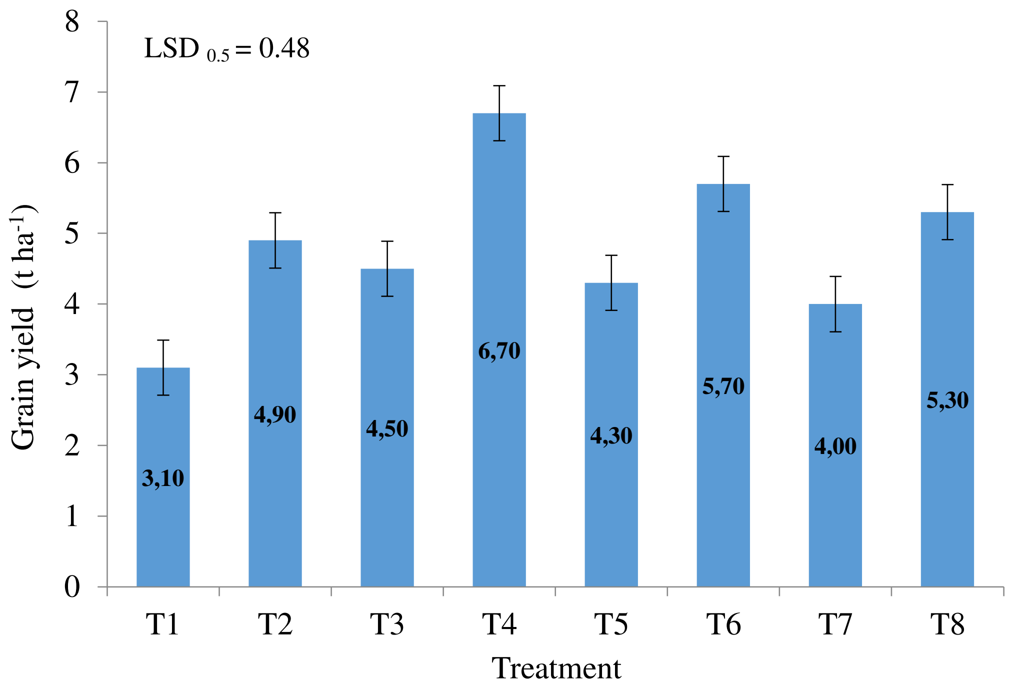


Figure 4. Grain yield of BRRI dhan87 as affected by different organic and inorganic fertilizer in Aman 2019 at Research Farm of SAU, Dhaka.

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

4.10. Straw yield (t/ha)

Different types of organic and inorganic fertilizers combination treatments showed significant differences on straw yield of BRRI dhan87. The experiment showed that among all treatment highest yield per hectare (6.70 t ha^{-1}) was obtained from T_4 (T_2 + 75kg mustard oil cake) treatment which was statistically significant with all other treatments and lowest yield per hectare (6.10 t ha^{-1}) was obtained from T_1 (control) (Figure 4). It was observed that highest straw yield of rice was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers whichwas supported by BRRI, (2004). Experiment revealed that application of organic and inorganic fertilizer gives highest yield per hectare. Adequate amount of nutrient availability of nutrients in soil increase the vegetative growth which results in higher plant height and more tillers which helps to increase the total straw yield of rice.

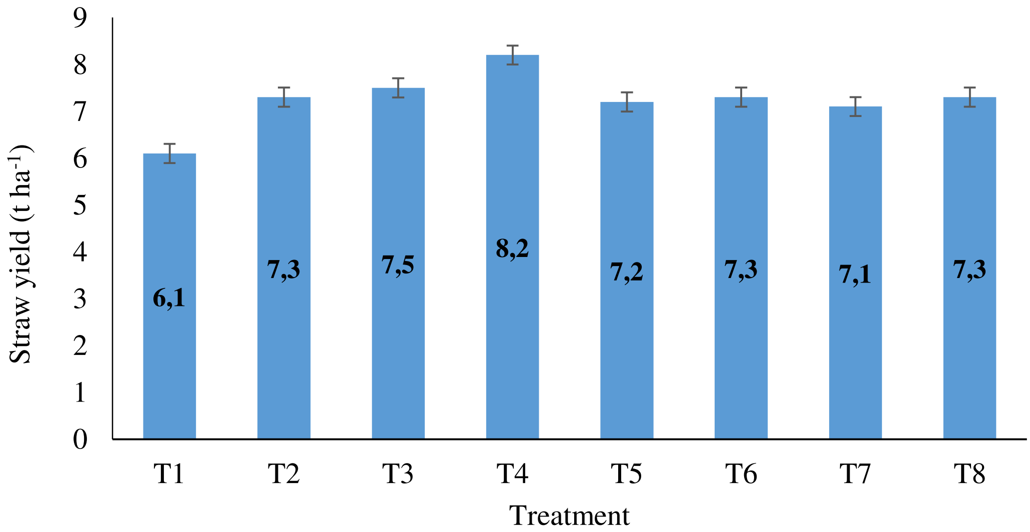


Figure: Straw yield of BRRI dhan87 as affected by different organic and inorganic fertilizer in Aman 2019 at Research Farm of SAU, Dhaka.

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

4.11. Harvest Index:

Different types of organic and inorganic fertilizer combination treatments showed significant differences on harvest index of BRRI dhan87. The experiment showed that among all the treatments, the highest harvest index (45%) was obtained from T_4 (T_2 + 75 kg mustard oil cake) treatment which was statistically significant compared to all other treatments and the lowest harvest index (33.7%) was obtained from T_1 (control) (Figure 4). It was observed that the highest harvest index was obtained from the application of mustard oil cake 75 kg ha^{-1} along with recommended chemical fertilizers which supported by BRRI, (2004). Experiment revealed that application of organic and inorganic fertilizer gives highest harvest index. Adequate amount of nutrient availability of nutrients in soil increase the number of effective tillers, panicle number and filled grain which helps to increase the total yield of rice. It also increases the vegetative growth which results in higher plant height and more tillers which help to increase the total straw yield of rice and result higher harvest index.

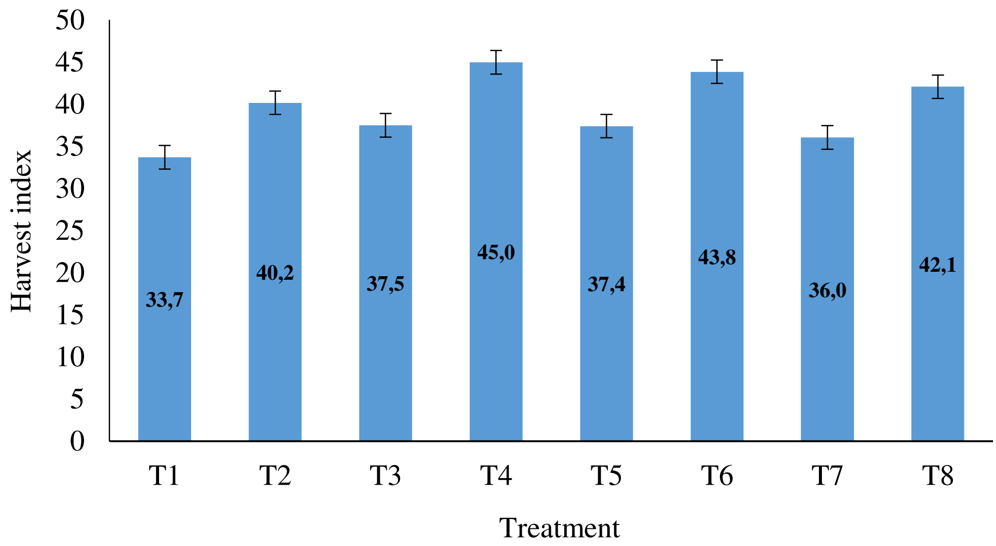


Figure: Harvest Index of BRRI dhan87 as affected by different organic and inorganic fertilizer in Aman 2019 at Research Farm of SAU, Dhaka.

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

4.3 Post-Harvest properties of soil

4.3.1 pH of Post-Harvest Soils

No significant variation was recorded in post-harvest soil pH due to the application of different organic and inorganic fertilizer for BRRI dhan87 cultivation (Appendix: IV). Although there was no significant difference among the treatments, the highest pH (6.3) of post-harvest soil was found from T_2 (RFD) which was statistically identical with others. The lowest pH (5.8) of post-harvest soil was recorded from T_3 (T_2 + 75 kg mustard oil cake).

4.3.2 Organic matter content of post-harvest soil (%)

Experimental data showed statistically significant effects of organic and inorganic fertilizer on organic matter status of post-harvest soils (Appendix: IV). The maximum organic matter (1.39 %) of post-harvest soil was found from T_4 (½ T_2 + 75kg mustard oil cake) which was statistically similar with T_2 (1.32%) and T_6 (1.33%) (Table 4). The lowest organic matter content (1.10 %) of post-harvest soil was recorded from T_1 control (No fertilizer).

4.3.3 Total N content (%)

Total N in post-harvest soil showed statistically significant differences due to the effect of different organic and inorganic fertilizer treatments (Appendix: IV). The highest (0.068%) total N was found from T_4 treatment which was statistically similar to T_6 treatment while the lowest (0.034 %) soil total N was observed from T_1 (control) treatment (Table 4).

4.3.4 Available P content (%)

Available P content in post-harvest soil showed statistically significant differences due to the effect of different organic and inorganic fertilizer treatments (Appendix: IV). The highest (37.80 %) available P was observed from T_4 treatment which is statistically similar to T_6. The lowest (18.31%) available P was found from T_1 (control) treatment.

4.3.5 Exchangeable K content (ppm)

Statistically significant difference was recorded in terms of exchangeable K in post-harvest soil due to different organic and inorganic fertilizer treatments (Appendix: IV). The highest (0.167 ppm) exchangeable K was observed from T_4 treatment which was statistically similar to T_6. The lowest (0.118 ppm) exchangeable K was recorded from T_1 treatment which was statistically similar to T_5 and T_7.

Table 4: Effect of different fertilizer management treatments on post-harvest soil properties

Treatments	pH	Organic matter content (%)	Total N content (%)	Available p content (ppm)	Exchangeable K content (meq/100g)
T_1	5.9	**1.10 d**	**0.034 e**	**18.31 e**	**0.118 e**
T_2	6.3	**1.32 abc**	0.053 c	33.12 bc	0.133 cd
T_3	5.8	1.31 bc	0.053 c	30.37 cd	0.131 d
T_4	5.9	**1.39 a**	**0.068 a**	**37.80 a**	**0.167 a**
T_5	6.1	1.26 bc	0.041 d	29.57 d	**0.129 de**
T_6	6.2	**1.33 ab**	**0.065 a**	**35.35 ab**	**0.155 ab**
T_7	6.2	1.25 c	0.040 d	29.41 d	**0.128 de**
T_8	6.1	1.31 bc	0.059 b	33.23 bc	0.145 bc
LSD $_{(0.05)}$	**NS**	**0.08**	**0.005**	**3.40**	**0.013**
C. V. (%)	**7.6**	**3.50**	**6.020**	**6.29**	**5.360**

T_1= No fertilizer (Control), T_2= Recommended fertilizers (RF), T_3= ½ T_2 + 75 kg ha^{-1} Mustard Oil Cake (MOC), T_4= T_2 + 75 kg ha^{-1} MOC, T_5= ½ T_2 + 3.7 t ha^{-1} Poultry Manure (PM), T_6= T_2 + 3.7 t ha^{-1} PM, T_7= ½ T_2 + 5 t ha^{-1} Cowdung and T_8= T_2 + 5 t ha^{-1} Cowdung.

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, fixation, 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, Dhaka, Bangladesh during the Aman season of July to November 2019 to investigate the effect of organic and inorganic fertilizers on the growth, yield, and yield components of wet season rice CV., BRRI dhan87 and to find out suitable combination of organic and inorganic fertilizers for maximum yield of BRRI dhan87..

There were eight treatments combinations consisting of different source of organic and inorganic fertilizer. The treatments were, T1= Control (No fertilizer applied), T2= N_{83} P_{15} K_{55} S_{10} Zn_1 kg (Recommended fertilizers dose, BRRI, 2020), T3= ½ T2 + 75 kg ha^{-1}mustard oil cake (MOC), T4= T2+ 75 kg ha^{-1} MOC, T5= $^1/_2$ T2 + 3.7 t ha^{-1} Poultry manure (PM), T6= T2+ 3.7 t ha^{-1} PM, T7= $^1/_2$ T2+ 5 t ha^{-1}Cowdung, and T8 = T2+ 5 t ha^{-1}Cowdung.

At harvest, the tallest plant (128.2 cm) was recorded in the treatment T_4 followed by T_6 (119.9 cm) and the shortest plant height (96.1 cm) was recorded in the T_1 (control). Maximum number of tillers $hill^{-1}$ was found in T_4 (22.5) and the minimum was found in T_1 (14.5). The highest number of effective tillers $hill^{-1}$ (18.9) was obtained in the T_4 (T_2 + 75 kg ha^{-1} mustard oil cake) treatment which was statistically significant compared to all other treatments. The 2nd highest effective tillers $hill^{-1}$ (16.4) was obtained in the T_6 (T_2 + poultry manure 3.7 t ha^{-1}) treatment. The minimum number of effective tillers $hill^{-1}$ (9.1) was obtained in the T_1 (no fertilizer).

At harvest, the longest panicle length (32.8 cm) was obtained from T_4 (T_2 + 75 kg ha^{-1} mustard oil cake) followed by T_6 (28.8 cm) and the shortest panicle length (20.1 cm) was obtained from T_1 (control). The highest number of grains $panicle^{-1}$ (125.2) was obtained from T_4 and the lowest number of grains $panicle^{-1}$ (109.7) was obtained from

T_1 (control). Similarly, the highest grains panicle^{-1} (97.1) was obtained from T_4 followed by T_6 (91.5) and the lowest grains panicle^{-1} (71.1) was obtained from T_1 (control). Similar trend also observed in case of unfilled grains panicle^{-1}. Among all treatments T_4 produced the highest weight (24.3 g) of 1000-grains while T_1 produced the minimum weight (21.5 g) of 1000-grains. The highest grain yield (6.70 t ha$^{-1)}$ of BRRI dhan87 was obtained T_4 (T_2 + 75 kg ha^{-1} mustard oil cake) treatment and the lowest grain yield (3.10 t ha^{-1}) was in T_1 (control). In case of straw yield, the treatment T_4 produced the highest straw yield (8.2 t ha$^{-1)}$ while the lowest straw yield (6.10 t ha^{-1}) was in T_1 (control). Among all the treatments, the highest harvest index (45.0%) observed in T_4 produced and the lowest (33.7 %) was in T_1.

Conclusion

It can thus be concluded from the research results that the combination of organic and inorganic fertilizers had significant positive effects of on the growth, yield, and yield components of wet season rice BRRI dhan87. Among the treatments, T_4 (N_{83} P_{15} K_{55} S_{10} $Zn_{1.5\ kg\ ha}^{-1}$ + 75 kg ha^{-1} mustard oil cake) performed the best to attaining highest yield and harvest index. Moreover, mustard oil cake performed the best compared to poultry manure and Cowdung applied along with chemical fertilizers. The vegetative and yield contributing characteristics like plant height, panicles m^{-2}, grains $panicle^{-1}$, panicle length, 1000-grain weight, followed the similar trend to yield. Therefore, the treatment T_4 (N_{83} P_{15} K_{55} S_{10} $Zn_{1kg\ ha}^{-1}$ + 75 kg ha^{-1} mustard oil cake) might be recommended for sustainable and successful cultivation of BRRI dhan87 to obtained better performance and higher yield.

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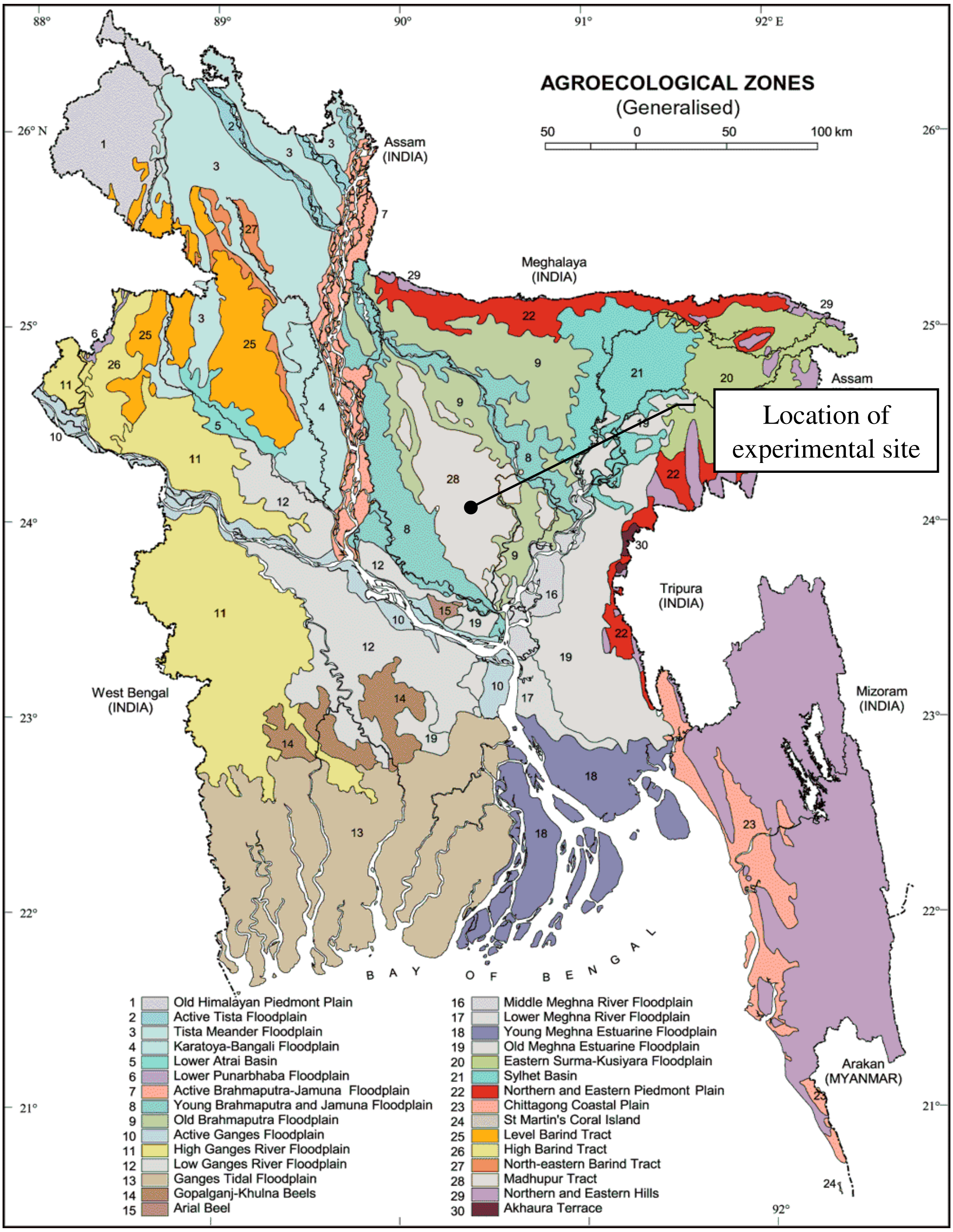
APPENDICES

Appendix I: Map showing the location of the site of the experiment.



Appendix II: Morphological characteristics of the experimental field.

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

Source: (FAO and UNDP, 1988)

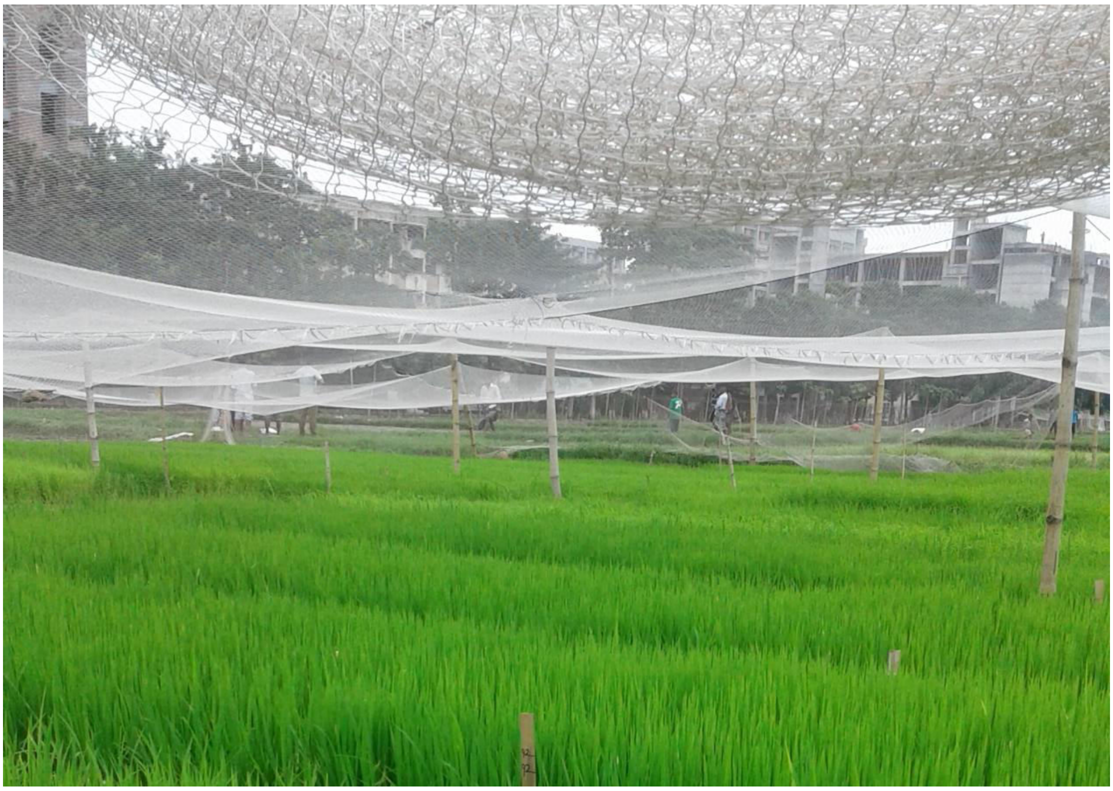
Appendix III: Physical and chemical properties of the soil

Characteristics	Value
Particle size analysis	
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
Consistency	Granular and friable when dry
pH	5.6
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.53
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.06
Available P (ppm)	20.0
Exchangeable K (meq/100g soil)	0.12

Source: SRDI, 2015

Appendix IV: Image showing sowing of seedling

Appendix V: Image showing overview of field



Appendix VI: Image showing experiment field

Appendix VII: Image showing rice panicle