EFFECT OF IRRIGATION, FERTILIZER AND MANURE ON THE GROWTH AND YIELD OF T. AMAN RICE

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF IRRIGATION, FERTILIZER AND MANURE ON THE GROWTH AND YIELD OF T. AMAN 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 *bona fide* research work carried out by **Rajib Chandra Bosak, Registration No. 08-03116** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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..……………………
Dated:
Place: Dhaka, Bangladesh

(Dr. Md. Asaduzzaman Khan)
Professor
Supervisor

DEDICATED

TO

MY

BELOVED PARENTS

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All praises to the Almighty God who enable me to complete a piece of research work and prepare this thesis for the degree of Master of Science (M.S.) in Soil Science.

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ABSTRACT

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2013 to November 2013 to study the effect of various organic manure and inorganic fertilizer with different water management on the growth and yield of T. Aman rice. BRRI dhan 32 was used as the test crop in this experiment. The experiment consists of 2 factors i.e. irrigation and fertilizer plus manure. Two levels of irrigations (I_1=Continuous flooding and I_2=Saturated condition) were used with 8 levels of fertilizer & manure, as T_0: Control, T_1: 100% $N_{120}P_{25}K_{60}S_{20}Zn_2$ (Recommended dose), T_2: 50% NPKSZn + 5 ton cowdung/ha, T_3: 70% NPKSZn + 3 ton cowdung/ha, T_4: 50% NPKSZn + 5 ton compost/ha, T_5: 70% NPKSZn + 3 ton compost/ha, T_6: 50% NPKSZn + 3.5 ton poultry manure/ha and T_7: 70% NPKSZn + 2.1 ton poultry manure/ha, with 16 treatment combinations and 3 replications. At the harvest, the yield parameters and yields were recorded; the irrigation had no significant single effect on the yield and yield parameters. The yield contributing characters and yield were significantly affected by fertilizer and manure and the highest effective tillers/hill (10.00), plant height (112.73 cm), panicle length (23.82 cm), no. of filled grains/panicle (94.20), 1000 grain wt. (21.90 g), grain yield (4.70 t/ha) and straw yield (6.58 t/ha) were found from T_5 (70% NPKSZn + 3 ton compost/ha), T_1 (100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$), T_1 (100% Recommended Dose), T_1 (100% Recommended Dose), T_6 (50% NPKSZn + 3.5 ton poultry manure/ha), T_4 (50% NPKSZn + 5 ton compost/ha) and T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatments, respectively. The higher grain yield was found by the application of organic plus inorganic fertilizers compared to the use of chemical fertilizer alone. The yields were influenced by combined application of irrigation and fertilizer and the highest grain yields (4.87 t/ha) was recorded from I_2T_4 (Saturated condition + 50% NPKSZn + 5 ton compost/ha) which was similar to the yield of I_1T_6, I_1T_7, I_2T_6 & I_2T_7 treatment combinations. The lowest grain yields (3.07 t/ha) was recorded from I_1T_0 (Continuous flooding + control) treatment combination. The higher concentrations of pore-water P & K were observed in the treatments where organic plus inorganic fertilizers were used combindly. The grain yield and nutrient concentrations were positively correlated with the pore-water P & K concentrations.

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CHAPTER-1

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa*) is the most extensively cultivated cereal in Bangladesh and it serves as the staple food for the people. Rice is one of the major crops of the world. Rice is a semi aquatic annual grass plant and is the most important cereal crop in the developing world. The economy of Bangladesh is remarkably influenced by rice and it was grown in 10.78 million hectares of land in 2002-2003 with a total production of 25.19 million tons. Although the geographical, climatic and edaphic conditions of Bangladesh are favorable for the year round rice cultivation. Rice is the major staple food of nearly half of the world's population, and is particularly important in Asia, where approximately 90% of world's rice is produced and consumed. It is estimated that by the year 2025, the world's farmers should be producing about 60% more rice than at present to meet the food demands of the expected world population at that time.

The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. As it is not possible to have horizontal expansion of rice area, rice yield should be increased to meet this ever increasing demand of food. The depleted soil fertility is a major constraint to higher crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrients in soils. Rice-rice cropping system is the most important cropping system in Bangladesh. Continuous cultivation of this highly exhaustive cropping sequence in most of the irrigated fertile lands has resulted in the decline of soil physico-chemical condition in general and particularly soil organic matter (SOM) content. Organic matter decomposition, nutrient mineralization, leaching and efficiency of fertilizer and manures in rice field are greatly affected by the soil moisture level.

The bioavailability, uptake of nutrients in soil is dependent on soil moisture and the source of nutrient in soil. Pore-water nutrient is considered to be the pool of nutrient that is most readily available for plant uptake. This research work focuses on better understanding of the solubility of N, P & K in pore water and its accumulation in rice. It is necessary to place greater emphasis on strategic research to increase the efficiency of applied nutrients through integration with organic manures with different moisture level. Among the factors affecting crop production, fertilizer in general is the single most important factor that plays a crucial role in yield increase if other production factors are not limiting. It is reported that chemical fertilizers hold the key to success of crop production systems of Bangladesh agriculture, being responsible for about 50% of the total crop production. So, higher yield of rice could be achieved if the crops are fertilized with optimum doses of nutrients. But the rice fertilization in Bangladesh is often considered below the optimum level to achieve the potential yield. Among the fertilizers, nitrogen plays a vital role in rice production.

Organic manure can supply a good amount of plant nutrients thus can contribute to crop yields. Thus, it is necessary to use fertilizer and manure in an integrated way in order to obtain sustainable crop yield without affecting soil fertility. The integrated approach by using the organic and inorganic sources of nutrients helps to improve the efficiency of nutrients. Mineralization and immobilization are biochemical in nature and are mediated through the activities of microorganisms. The rate and extent of mineralization determines crop availability of nutrients. The transformation of N, P and S in soil depends on the quality and quantity of organic matter as well as soil fertility and microbial activity.

This study was under taken with the following objectives:

I. To evaluate the effects of combined application of inorganic and organic fertilizers with different water management on the yield, yield components of T. Aman rice.

II. To find out the availability of P and K in pore water of T. Aman rice cropped soil with different fertilizer application.

III. To find out a suitable integrated dose of inorganic fertilizers combined with different manures for T. Aman rice.

IV. To assess the influence of crop characters on the grain and straw yields of rice.

CHAPTER-2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Soil organic manure and inorganic fertilizer is the essential factor for sustainable soil fertility and crop productivity. Because it is the store house of plant nutrients. Sole and combined use of cow dung, poultry manure, compost, and inorganic fertilizer acts as a source of essential plant nutrients. Experimental evidences in the use of cow dung, poultry manure, compost, and nitrogen, phosphorus, potassium and sulphur showed an intimate effect on the yield and yield attributes of rice. Yield and yield contributing characters of rice are considerably influenced by different doses of NPKS fertilizer and cow dung, poultry manure & compost manure and their combined application. Irrigation is also an important factor for sustainable soil fertility and crop productivity. Some literature related to the "Effect of irrigation, fertilizer and manure on the growth and yield of T. Aman rice cv. BRRI dhan 32" are reviewed below:

2.1 Effect of chemical fertilizer on the growth and yield of rice

Ndaeyo *et al.* (2008) conducted an experiment in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600kg/ha). The results showed that 600kg/ha NPK (15:15:15) fertilizer rate significantly ($P < 0.05$) increased plant height, number of leaves and tillers per plant in both years. The 400kg/ha rate increased the number of panicles per plant, length of central panicle per plant and the overall grain yields, straw yield over other rates by 4-32% and 2-21% in 2005 and 2006, respectively.

Rasheed *et al.* (2003) reported that the effect of different NP levels i.e., 0-0, 25-0, 50-25, 75-50, 100-75 and 125-100 kg ha^{-1} on yield and yield attributes of rice Bas-385. Yield attributes (No. of effective tillers per hill, spikelet per panicle, normal kernels per panicle, 1000-grain weight) were improved linearly with increasing NP levels up to 100-75 kg/ha. The NP level of 100-75 kg/ha resulted in the highest grain yield of 4.53 t ha^{-1} with minimum kernel abnormalities (Sterility, abortive kernels and opaque kernels) as against the minimum of 2.356 t/ha in the control (0-0) followed by 25-0 kg NP/ ha with maximum kernel abnormalities.

Haq *et al.* (2002 a) reported that the number of panicles increased with increase in the nitrogen rates and that number of panicles per plant increased with increase in NPK rates.

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of NPK increase Plant height.

Singh *et al.* (2003 a) also reported that crop growth rate and relative growth rate such as total dry matter production was significantly influenced by NPK. The tiller number and total dry matter production are closely correlated with yield depending on the rice cultivar (Tanaka, 1968) which can be greatly enhanced by applying proper nutrient.

Singh *et al.* (2003 b) reported that crop growth rate, such as plant height, dry mater production averaged across treatments, was highest at 45-60 days after transplanting of rice and significantly influence by NPK fertilizers.

Saha *et al.* (2004) conducted an experiment in 2002-2003 to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one check plot. Results show that the application of different packages estimated by different fertilizer models significantly influence panicle length, panicle numbers, spikelet number per panicle, total grains panicle^{-1}, number of filled grain and unfilled grain per panicle. The combination of NPK that gives the highest result was 120-13-70-20 kg/ha NPKS.

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

Asif *et al.* (2000) reported that NPK levels significantly increase the panicle length, number of primary and secondary branches panicle^{-1} when NPK fertilizer applied in 180-90-90 kg ha^{-1} this might be attributed to the adequate supply of NPK.

2.2 Combined effects of chemical fertilizer and manure on the growth and yield of rice

2.2.1 Combined effects of chemical fertilizer and cowdung on the growth and yield of rice

Rahman *et al*. (2009) conducted a field experiment to study the effect of urea N in combination with poultry manure and cowdung in rice and found application of manures and different doses of urea N fertilizer significantly increased the yield components and grain and straw yields.

Saleque *et al*. (2004) conducted a field experiment to determine the effect of different doses of chemical fertilizers alone or in combination with cowdung (CD) and rice husk ash on yield of lowland rice-rice cropping sequence. Cowdung and ash were applied on dry season rice only and found the application of cowdung and ash increased rice yield by about 1 t/ha per year over that obtained with chemical fertilizer alone, the treatments, which showed positive yield trend, also showed positive total P uptake trend and positive yield trends were attributed to the increasing P supplying power of the soil.

Tripathy *et al*. (2004) found significantly higher seed yield under the residual effects of the blended cowdung and NPK fertilizer compared to the control.

Saitoh *et al.* (2001) conducted an experiment to evaluate the effect of organic fertilizers (cowdung and poultry manure) and pesticides on the growth and yield of rice and revealed that the yield of organic manure treated and pesticide free plots were 10% lower than that of chemical fertilizer and pesticide treated plot due to a decreased in the number of panicle. Yearly application of manure increased the total carbon and nitrogen content in soil.

Dao and Cavigelli (2003) reported that animal manure had long been used as an organic source of plant nutrients and organic matter to improve the physical and fertility condition of agricultural lands.

2.2.2 Combined effects of chemical fertilizer and poultry manure on the growth and yield of rice

Miah *et al*. (2006) stated that an application of poultry manure with soil test basis (STB), IPNS and AEZ based fertilizer gave higher grain yield compared to other organic materials.

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.

Reddy *et al*. (2005) carried out a field experiment on black clay soils in Gangavati, Karnakata, India, to evaluate the performance of poultry manure (PM) as a substitute for NPK in irrigated rice (cv. IR 64). The application of PM at 5 t/ha recorded a significantly higher grain yield (5.25 t/ha) than the control and FYM application at 7.5 t/ha, significantly improved the soil P and K status, and increased the N content of the soil. Poultry manure at 5 t/ha resulted in higher gross returns (30592 Rupees/ha) over other levels of PM and FYM. However, net returns and benefit cost rations were comparable between 5 and 2 t PM/ha, and between 100 and 75% NPK. The application of 2 t PM/ha and 75% NPK was found economical.

Miah *et al*. (2004) found 5.6-6 t/ha-grain yields with application of 2 t/ha poultry manure plus 120 kg N/ha in T. Aman season.

Channabasavanna (2003) conducted a field experiment to evaluate the efficient utilization of poultry manure with inorganic fertilizers in wetland rice and found that the grain yield increased with each increment of poultry manure application and was maximum at 3 t poultry manure/ha. Poultry manure at 2 ton /ha recorded significantly higher values for seed yield and its attributes. The study proved the superiority of poultry manure over farmyard manure (FYM). It was evident from the study that one ton of poultry manure was equivalent to 7 ton FYM which produced at per seed yields. Agronomic efficiency of N (AEN) at 75% NPK (112.5:56.3:56.3 kg NPK/ha) was equivalent to 2 t poultry manure/ha. The results showed that an increase in poultry manure and fertilizer increased rice seed yield. The AEN decreased with an increase in the application of poultry manure and NPK fertilizer.

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

Eneji *et al*. (2001) observed that average across the soils, the level of extractable Fe increased by 5% in chicken manure and 71% in cattle manure; Mn by 61% in chicken manure and 172% in swine manure and Cu by 327% in chicken manure and 978% in swine manure. Mixing these manures before application reduce the level of extractable trace elements.

Vanjau and Raju (2002) conducted a field experiment on integrated nutrient management practice in rice crop. Different combinations of chemical fertilizer with poultry manure (PM) 2 t/ ha gave highest grain and straw yield.

2.2.3 Combined effects of chemical fertilizer and compost on the growth and yield of rice

Aga *et al*. (2004) assessed the effect of compost on the growth and yield of rice. Plant growth characters such as plant height were highest with application of 15 t compost/ha.

Grain yield increased significantly with the graded levels of compost application @ 10 t/ha but the response decreased with the increase of compost from 10 to 15 t/ha.

Nayak *et al* (2007) reported that application of compost and inorganic fertilizer increased microbial growth in soil, vegetative growth and maximum tillering of rice.

Ali *et. al (*2009) conducted a field experiment to evaluate the suitability of different sources of organic materials for integrated use with chemical fertilizers for the Boro-Fallow-T. Aman rice cropping pattern. Eight treatments, formulated from organic manure and chemical fertilizers have been imposed. The treatment combinations are T_1: control, T_2: 70% NPKS, T_3: 100% NPKS, T_4: 70% NPKS + rice straw (RS) @ 5 t/ha, T_5: 70% NPKS + dhaincha (DH) @ 15 t/ha, T_b: 70% NPKS + mungbean residue (MBR) @ 10 t/ha, T_7: 70% NPKS + cowdung (CD) @ 5 t/ha and T_8: 70% NPKS + poultry manure (PM) @ 3 t/ha. Organic manure or crop residue was applied to T. Aman rice and their residual effects were observed in the following Boro rice. Application of 70% NPKS + PM produced the highest grain yield of T. Aman rice, which was identical to that obtained with 100% NPKS with no manure. In Boro season application of 100% NPKS produced the highest grain yield of 6.87 t/ha, which was identical with the application of 70% NPKS + PM (6.57 t/ha). The total grain yield in the cropping pattern ranged from 5.14 t/ha in T_1 (control) treatment to 12.29 t/ha in the 100% NPKS. The application of 3 t/ha PM with 70% NPKS (T_8) produced the total yield of 12.09 t/ha followed by 11.59 t/ha in the treatment containing 10 t/ha MBR plus 70% NPKS (T_6). It appears that the application of 3 t/ha PM once in a year with 70% NPKS can reduce the use of 30% NPKS as fertilizers. There were negative balances for N and K with the highest mining.

Davarynejad *et al.* (2004) conducted an experiment to investigate the effect of manure and municipal compost and their enrichment with chemical fertilizers on growth and yield of rice. Results showed that compost alone did not increase grain yield. However, when enriched with different levels of chemical fertilizer the highest amount of grain yield was produced. The yield was comparable to the yield obtained from 40 t/ha of compost. This indicated that compost might be an appropriate substitute for manure and half of chemical fertilizer needed for soil.

Farid *et al*. (1998) reported that incorporation of compost or rice straw and subsequent decomposition increased and maintained organic matter level at 2.5% that was higher than that in traditionally managed rice soil (<2%).

Tamaki *et al*. (2002) observed that the correlation between growth and yield and duration of organic farming (compost mixed with straw) in comparison with conventional farming. In inorganic farming plant height of rice was shorter and short number/hill was lesser than in conventional farming, but both of these values increased as the duration of organic farming increased. The maximum tiller number was smaller and panicle number was also smaller than in inorganic farming. However, both the panicle number and panicle length increased as the duration organic farming increased. The grain- straw ratio was higher in organic farming than the conventional farming. These results suggest that the growth and yield of rice increased with continuous organic farming and the yield increased with increase in panicle number/hill and grain number/panicle.

Keeling *et al*. (2003) determined the green waste compost and provided with additional fertilizers and showed consistently that the response of rice rape to compost and fertilizer applied together than the response to the individual additives, but only very stable compost was used (> 10 months processing). Experiments with 15 N-labeled fertilizer showed that rice was able to utilize the applied N-more efficiently when cultivated with the stable compost.

Elsharawy *et al*. (2003) found the effect of compost of the some plant residues i.e. rice straw and cotton stalk on some physical and chemical properties of the sandy soil. Application of cotton stalks or rice straw composts significantly improved the physical properties of the tasted soil, i.e., bulk density, hydraulic conductivity and moisture content namely field capacity, wilting point and available water, concerning the effect of compost application on the availability of N, P and K in the cultivated soil, rice straw was better than cotton stalks.

Composts from organic wastes, such as segregated waste, green botanical waste and food processing waste are becoming available in increasing quantities. These supply a complex mixture of nutrients in organic and mineral forms and are also used as soil condition to maintain and improve soil structure (HDRA, 1999).

2.3 Effect of irrigation on growth and yield of rice

Thakur *et al*. (2011) observed that system of rice intensification practices with alternate wet and drying improve rice plants morphology and it benefits physiological processes that results in higher grain yield water productivity.

Ebrahim *et al*. (2011) conducted experiment with four water management (I_1: submerge irrigation, I_2: 5 day interval, I_3: 8 day interval, I_4: 11 day interval) and showed highest grain yield was found from submerge irrigation (I_1) and also 90 kg /ha nitrogen fertilizer consumption.

Lin *et al*. (2011) reported that intermittent water application with SRI management, grain yield increased by 10.5 and 11.3%, compared to standard irrigation practice (continuous flooding). They also reported that intermittent irrigation with organic material application improved the function of rhizosohere and increased yield of rice.

Zhao *et al*. (2011) found that total water use efficiency and irrigation water use efficiency was increased with system of rice intensification (SRI) by 54.2 and 90% respectively. Thus, SRI offered significantly greater water saving while at the same time producing more grain yield of rice in these trials 11.5% more compared to traditional flooding.

Gani *et al*. (2002) reported that intermittent (alternate wet and drying) irrigation consistently performed better than continuously flooded irrigation, that is it produced more effective tillers, leaf area, and biomass.

Qinghua *et al.* (2002) carried out an experiment in rainproof containers to study the response of different varieties (Sanyou 10 and 923 and Zhensan 97B) of rice to three water treatments (flooded, intermittent and dry condition) and observed that grain yields in the dry cultivation treatment amounted to 6.3, 6 and 3.7 t/ha for the varieties Sanyou 10 and 923 and Zhensan 97B respectively. Under intermittent irrigation, yields of Sanyou 10 and 923 were 8% and 10% higher, 9.5 and 8.8 t/ha, respectively than under flooded condition. The highest yield of Zhensan 97B (5.3 t/ha) was obtained under flooded condition.

Uphoff and Randriamiharisoa (2002) observed that continuous flood irrigation constrain root growth of rice and contribute to root degeneration and it also limit soil microbial life to anaerobic populations. Keeping paddy fields flooded also restricts biological nitrogen fixation to anaerobic processes and affect plant growth.

2.4 Changes in soil fertility and properties due to integrated use of chemical fertilizers and manure

Ilma *et al*. (2012) conducted a field experiment to improve soil physical and chemical properties in organic agriculture. The incorporation of green manure crops, the application of compost and other organic fertilizers and amendments, combined with suitable soil cultivation practices are part of the practices, aimed at achieving this goal. The role of soil microorganisms in achieving optimal nutritional regime in organic agriculture was reviewed. Soil microbial flora control for the enhancement of the domination of the beneficial and effective microorganisms could prove to be a means for the improvement and maintenance of optimal physical and chemical soil properties in organic agriculture.

Golabi *et al.* (2007) observed that one of the major problems in agricultural soils is their low organic matter content, which results from rapid decomposition due to the hot and humid environment. Composted organic material is frequently applied on agricultural fields as an amendment to provide nutrients and also to increase the organic matter content and to improve the physical and chemical properties of soils.

Altieri *et al.* (2003) With the treatment and the other organic fertilizer treatments, it was observed that during the second season, soil organic matter, as well as soil nitrogen and phosphorus content, significantly increased over those values from inorganic fertilizer application.

Residual effects of organic fertilizer application were manifested with an increase in soil nutrient availability during the second season. This led to better plant growth, higher dry matter production, improved LAI, and higher plant tissue content of nitrogen and phosphorus. Similar data have been reported by Zayed *et al*. (2007, 2008).

Zayed *et al*. (2007, 2008) mention that organic fertilizer treatments reduced soil pH levels and more in the second season than in the first. Application of organic fertilizers, especially 5 t ha-1 RSC + 110 kg N ha-1, and 7 t FYM + 5 t RSC + *Azo*., significantly increased soil potassium, zinc and ferrous iron content in both seasons, with the second-season results being even higher.

Palm *et al*. (1997) found the positive impact of organic fertilizers on soil fertility improvement might be due to the following relationships. First, decomposition and mineralization of nutrients present in the organic material. Secondly, release of some organic acids as a result of organic decomposition which reduces the soil pH, while improving nutrient availability.

CHAPTER-3

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2013 to November 2013 to study the effect of various organic manure and inorganic fertilizer with different water management on the growth, yield of T. Aman rice and nutrient availability in soil during rice growing period. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings:

3.1 Experimental site and soil

The experiment was conducted in typical rice growing silt loam soil at the Sher-e-Bangla Agricultural University Farm, Dhaka during the T. Aman season of 2013. The morphological, physical and chemical characteristics of the soil are shown in the Table 3.1 and Table 3.2.

Table 3.1: Morphological Characteristics of the Experimental Field

Morphology	**Characteristics**
Location	SAU Farm, Dhaka
Agroecological 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

(FAO and UNDP, 1988)

Table 3.2: Initial Physical and Chemical Characteristics of the Soil

Characteristics		Value
Mechanical fractions:	% Sand (2.0-0.02 mm)	22.53
	% Silt (0.02-0.002 mm)	56.72
	% Clay (<0.002 mm)	20.75
Textural class		Silt Loam
pH (1: 2.5 soil- water)		5.9
Organic Matter (%)		1.09
Total N (%)		0.06
Available K (ppm)		15.63
Available P (ppm)		10.99
Available S (ppm)		6.07

3.2 Climate

The climate of the experimental area is characterized by scanty rainfall associated with moderately low temperature during the *kharif*-2 season. The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season July 2013 to November 2013 have been presented in Appendix I.

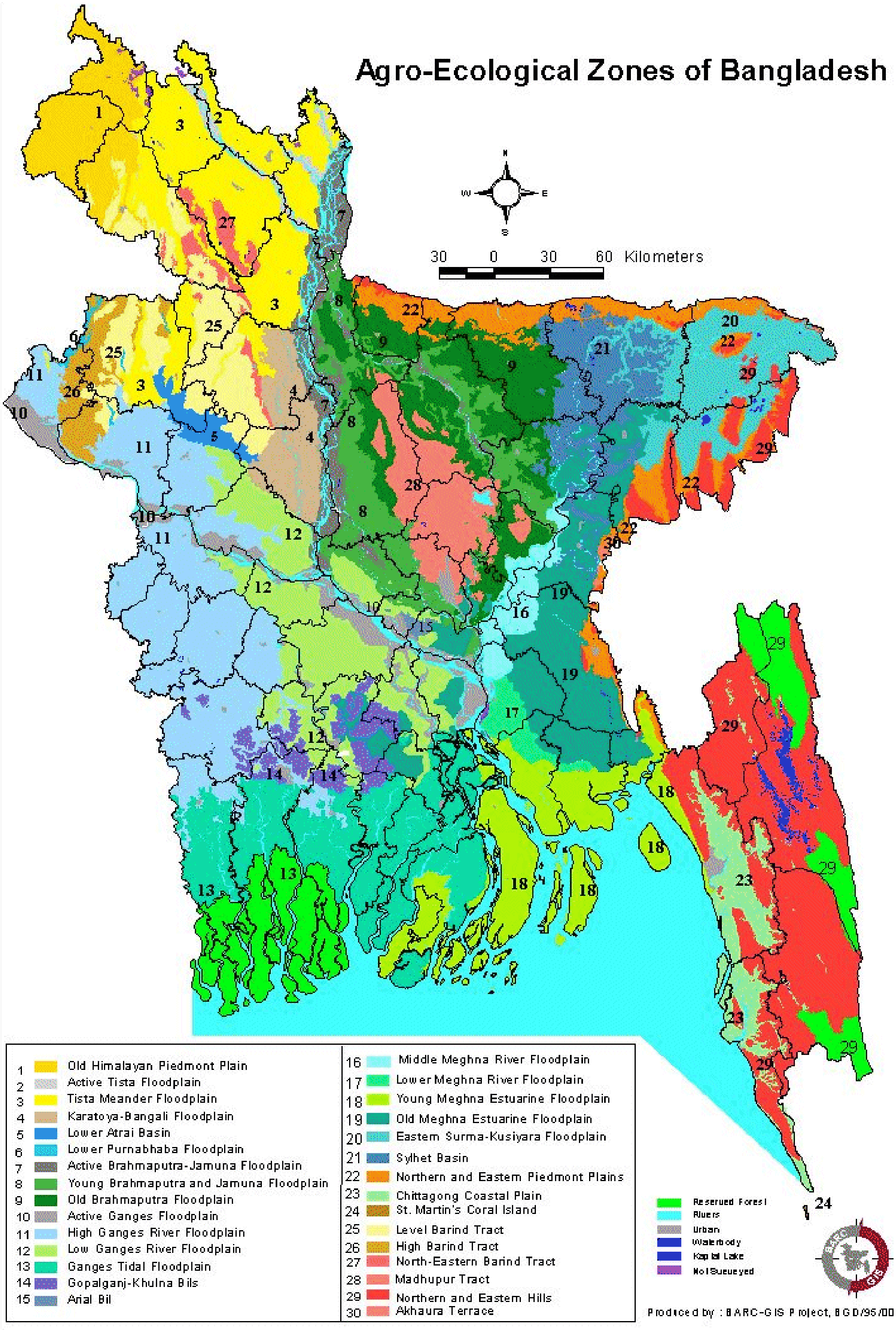

Figure 1: Agroecological zones of Bangladesh

3.3 Planting material

BRRI dhan 32 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute. It is recommended for T. Aman season. Average plant height of the variety is 110-115 cm at the ripening stage. The grains are medium fine and white. It requires about 120-130 days completing its life cycle with an average grain yield of 5.0-5.5 t/ha (BRRI, 2004).

3.4 Land preparation

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

3.5 Experimental design and layout

The experiment was laid out in a split plot design (SPD) with three replications. The layout was made distributing two irrigations (continuous flooding and saturated condition) to the main plots and fertilizer plus manure treatments to the sub plots. The total number of plots was 48, measuring 2.5 m × 2.0 m and ails separated plots from each other. The distance maintained between two main plots and two sub plots were 1.0 m and 0.5 m respectively.

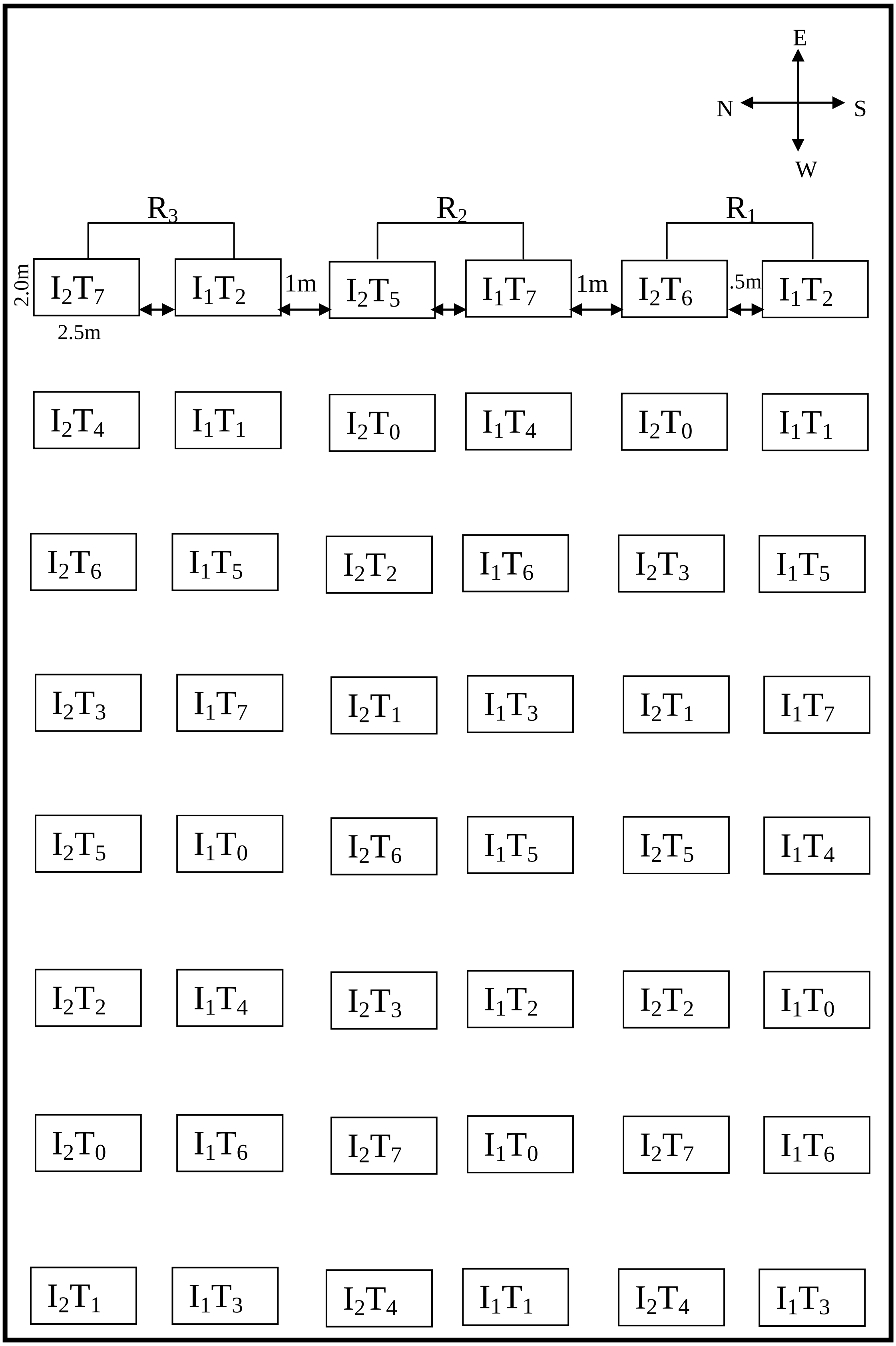

Figure 2: Layout of the experimental plot of T. Aman rice

3.6 Initial soil sampling

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

3.7 Treatments

The experiment consists of 2 factors i.e. irrigation and fertilizer plus manure. Details of factors and their combinations are presented below:

Factor A: 2 Level of Irrigation in the Main Plot

I_1 = Continuous flooding

I_2 = Saturated condition

Factor B: 8 Fertilizer, Manure Treatment in the Sub Plot

T_0: Control

T_1: 100% Recommended Dose ($N_{120}P_{25}K_{60}S_{20}Zn_2$)

T_2: 50% NPKSZn + 5 ton cowdung/ha

T_3: 70% NPKSZn + 3 ton cowdung/ha

T_4: 50% NPKSZn + 5 ton compost/ha

T_5: 70% NPKSZn + 3 ton compost/ha

T_6: 50% NPKSZn + 3.5 ton poultry manure/ha

T_7: 70% NPKSZn + 2.1 ton poultry manure/ha

Treatment Combination

I_1T_0 : Continuous flooding + Control

I_1T_1 : Continuous flooding + 100% Recommended Dose ($N_{120}P_{25}K_{60}S_{20}Zn_2$)

I_1T_2 : Continuous flooding + 50% NPKSZn + 5 ton cowdung/ha

I_1T_3 : Continuous flooding + 70% NPKSZn + 3 ton cowdung/ha

I_1T_4 : Continuous flooding + 50% NPKSZn + 5 ton compost/ha

I_1T_5 : Continuous flooding + 70% NPKSZn + 3 ton compost/ha

I_1T_6 : Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha

I_1T_7 : Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure/ha

I_2T_0 : Saturated condition + Control

I_2T_1 : Saturated condition + 100% Recommended Dose ($N_{120}P_{25}K_{60}S_{20}Zn_2$)

I_2T_2 : Saturated condition + 50% NPKSZn + 5 ton cowdung/ha

I_2T_3 : Saturated condition + 70% NPKSZn + 3 ton cowdung/ha

I_2T_4 : Saturated condition + 50% NPKSZn + 5 ton compost/ha

I_2T_5 : Saturated condition + 70% NPKSZn + 3 ton compost/ha

I_2T_6 : Saturated condition + 50% NPKSZn + 3.5 ton poultry manure/ha

I_2T_7 : Saturated condition + 70% NPKSZn + 2.1 ton poultry manure/ha

3.8 Fertilizer Application

The amounts of N, P, K, S and Zn fertilizers required per plot were calculated as per the treatments. Full amounts of TSP, MoP, Gypsum and Zinc sulphate were applied as basal dose before transplanting of rice seedlings. Urea was applied in 3 equal splits: one third was applied at basal before transplanting, one third at active tillering stage (30 DAT) and the remaining one third was applied at 5 days before panicle initiation stage (55 DAT).

3.9 Organic Manure Incorporation

Three different types of organic manure viz. cow-dung, poultry manure and compost were used. The rates of compost were 5 & 3 ton/ha & manure were 3.5 & 2.1 ton/ha respectively and 5 & 3 ton per ha for cow-dung, poultry manure and compost per plot were calculated as per the treatments, respectively. Cow-dung, compost and poultry manure were applied before four days of final land preparation. Chemical compositions of the manures used have been presented in Table 3.3.

Table 3.3: Chemical Compositions of the Cow-dung, Poultry Manure and Compost (oven dry basis)

Sources of organic manure	Nutrient content			
	N (%)	**P (%)**	**K (%)**	**S (%)**
Cow-dung	1.46	0.29	0.74	0.24
Poultry manure	2.2	1.99	0.82	0.29
Compost	1.49	0.28	1.60	0.32

3.10 Raising of Seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 5 kg per ha were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed whenever required.

3.11 Transplanting

Forty days old seedlings of BRRI dhan 32 were carefully uprooted from the seedling nursery and transplanted on 04 August, 2013 in well puddle plot. Two seedlings per hill were used following a spacing of 20 cm × 20 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.12 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.

3.12.1 Irrigation

T. Aman is cultivated in rainfed condition. So it is very difficult to maintain irrigation treatments in the main plots. When supplemented irrigation was applied, treatment wise irrigation levels were maintained. Necessary irrigations were provided to the plots as and when required during the growing period of rice crop. Irrigation treatment of saturated condition was not properly maintained due to rainy season.

3.12.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times during the period of the cropping season.

3.12.3 Insect and pest control

There was no infestation of diseases in the field but leaf roller (*Chaphalocrosismedinalis*, Pyralidae, Lepidoptera) was observed in the field and used Malathion @ 1.12 L ha^{-1}.

3.12.4 Pore-Water Collection

Pore-water samples were collected from outside of the cores during T. Aman rice growing period by using rhizon sampler (Rhizon MOM 10 cm length, 2.5 mm OD, Rhizosphere Research Products, Wageningen, and The Netherlands) during the different dates of rice growing periods. The pore-water samples were filtered through Whatman no. 42 filter paper and analyzed for N, P and K contents by standard method (Figure: 3 & 4).

Figure 3: Rhizon Sampler

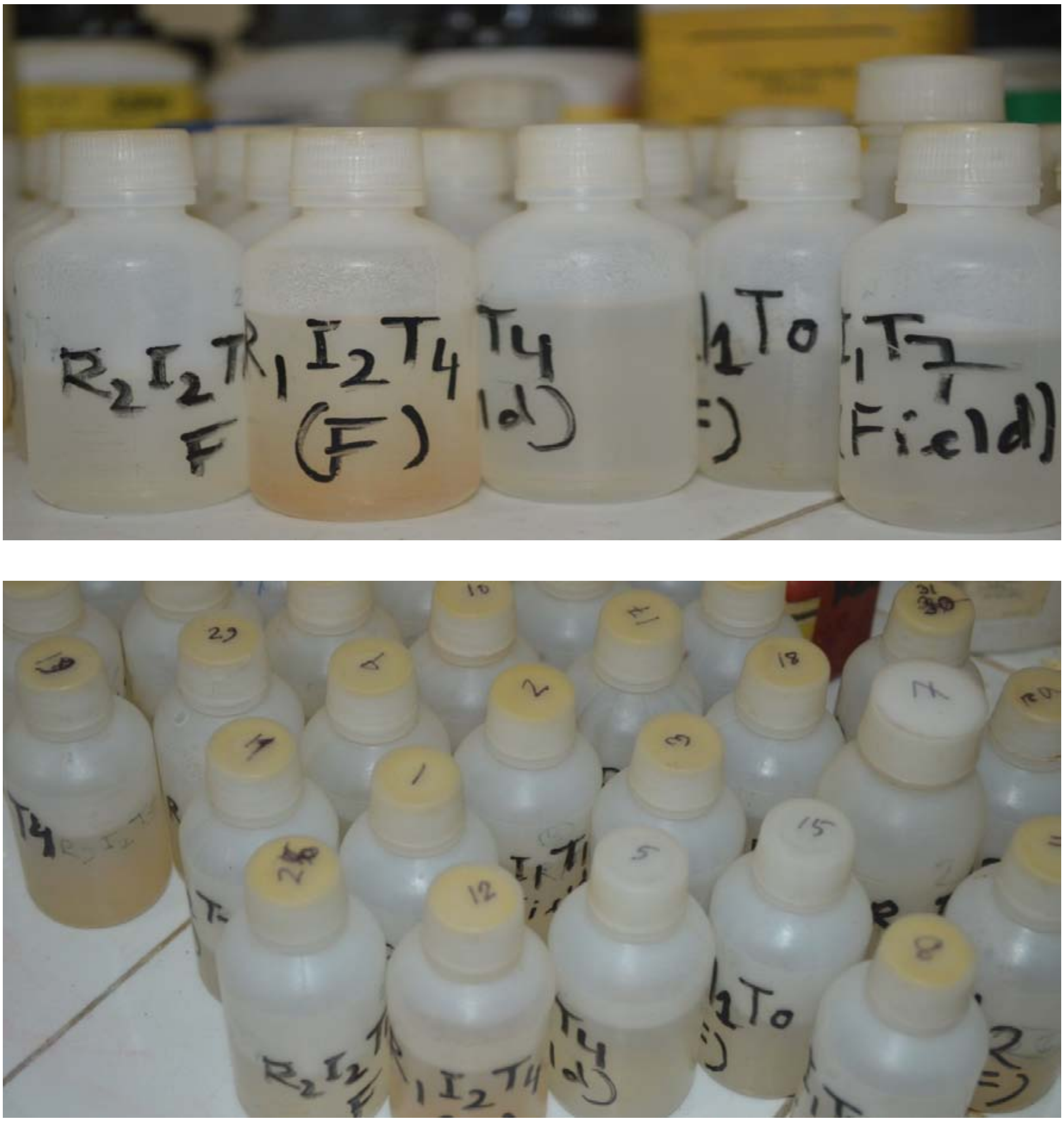

Figure 4: Pore Water Samples

3.13 Crop harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on November, 2013. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor. Eight hills of rice plant were selected randomly from the plants for measuring yield contributing characters.

3.14 Yield components

3.14.1 Total no. of effective tillers/hill

The total number of effective tiller/hill was counted as the number of panicle bearing hill/plant. Data on effective tiller/hill were counted from 8 selected hills and average value was recorded.

3.14.2 Total no. of non effective tillers/hill

The total number of non effective tiller/hill was counted as the number of non-panicle bearing plant/hill. Data on non effective tiller/hill were counted from 8 randomly selected hills and average value was recorded.

3.14.3 Plant height (cm)

The height of plant was recorded in centimeter (cm) at harvesting stage. Data were recorded as the average of 8 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.14.4 Length of panicle (cm)

The length of panicle was measured with a meter scale from 8 selected plants and the average value was recorded as per plant.

3.14.5 No. of filled and unfilled grains/panicle

The total numbers of unfilled grains were calculated from selected 8 plants of a plot on the basis of no grain in the spikelet and then average numbers of unfilled grain per panicle was recorded. Similarly filled grains/panicle was counted.

3.14.6 Weight of 1000 seeds (g)

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

3.14.7 Grain yield (kg)

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

3.14.8 Straw yield (kg)

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

3.15 Chemical analysis of plant samples

3.15.1 Collection and preparation of plant samples

Grain and straw samples were collected after threshing for N, P and K analysis. The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine (wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analysis of N, P & K. The grain sample was analyzed for determination of N, P & K concentrations. The methods were as follows:

3.15.2 Digestion of plant samples with sulphuric acid for N analysis

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_{4.}$ $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^{0}C and added 2 ml 30% H_2O_2 then heating was continued at 360 ^{0}C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.15.3 Digestion of plant samples with nitric-perchloric acid for P & K analysis

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. 10 ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^{0}C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. P & K were determined from this digest by using different standard methods.

3.15.4 Determination of P & K concentration from plant samples

3.15.4.1 Phosphorus

Plant samples (grain) were digested by di-acid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml grain sample from 100 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrical at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.15.4.2 Potassium

Five milli-liters of grain digest sample was taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.16 Pore Water Analysis

Pore water samples were analyzed for both physical and chemical characteristics viz. total N and available P and K contents. The Pore water samples were analyzed by the following standard method as follows:

3.16.1 Total Nitrogen

Total N content of pore water samples were determined followed by the Micro Kjeldahl method. 10 ml pore water 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. By operating the switch of the distillation apparatus distillate was collected. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

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

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in milliliter

3.16.2 Available Phosphorus

Phosphorus in the pore water was determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured by spectrophotometer at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al*. 1982).

3.16.3 Available Potassium

Readily available K was determined in pore water by using flame photometer and calibrated with a standard curve (Page *et al*. 1982).

3.17 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of BRRI dhan 32. The mean values of all the characters were calculated and analysis of variance was performed by M Stat-C. The significance of the difference among the treatment means was estimated by the Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez *et. al.*, 1984).

CHAPTER-4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results of pore-water nutrient availability, different yield attributes, yield and nutrient concentration in the plant and grains and consumption of nutrients by plants and grains of rice are presented this chapter.

4.1 Effective tiller

4.1.1 Effect of irrigation on the effective tillers/hill of T. Aman rice

The effects of irrigation on the effective tillers/hill of T. Aman rice are presented in (Table 4.1). Insignificant variation was observed on the effective tillers/hill of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_1 (Continuous flooding) showed the highest number of effective tillers/hill (9.25) and I_2 (Saturated Condition) irrigation showed lowest number of effective tillers/hill (9.05).

Table 4.1 Effect of irrigation on effective tillers/hill & non-effective tillers/hill of T. Aman rice

Treatments (Irrigation)	**No. of effective tillers/hill**	**No. of non-effective tillers/hill**
I_1	9.25	0.89
I_2	9.05	0.83
SE (±)	NS	NS

I_1= Continuous flooding

I_2= Saturated Condition

4.1.2 Effects of different doses of fertilizer and manure on the effective tillers/hill of T. Aman rice

Different doses of fertilizers showed insignificant variations in respect of effective tillers/hill of T. Aman rice (Table 4.2 & Figure 5). Among the different doses of fertilizers, T_5 (70% NPKSZn + 3 ton compost/ha) showed the highest number of effective tillers/hill (10.00) which was followed (9.73) by T_3 (70% NPKSZn + 3 ton cowdung/ha) treatment. The highest number of effective tillers/hill (10.00) found in T_5

treatment which was similar with all other treatment except T_4 (50% NPKSZn + 5 ton compost/ha). The same amount of fertilizer was added by different sources and produced almost similar number of effective tillers/hill. On the contrary, the lowest number of effective tillers/hill (8.00) was observed with T_4 (50% NPKSZn + 5 ton compost/ha), which were similar to T_0 (Control) & T_2 (50% NPKSZn + 5 ton cowdung/ha) treatments. Nayak *et al.* (2007) reported a significant increase in effective tillers/hill due to application of chemical fertilizer with organic manure. Similar results also found by Rahman *et al.* (2009) and Reddy *et al.* (2004).

Table 4.2 Effects of different doses of fertilizer and manure on effective tillers/hill & non-effective tillers/hill of T. Aman rice

Treatments	No. of effective tillers/hill	No. of non-effective tillers/hill
T_0	8.70	1.40 a
T_1	9.40	0.77 b
T_2	8.77	0.90 b
T_3	9.73	0.97 ab
T_4	8.00	0.70 b
T_5	10.00	1.00 ab
T_6	9.27	0.57 b
T_7	9.33	0.57 b
SE(±)	NS	0.13

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

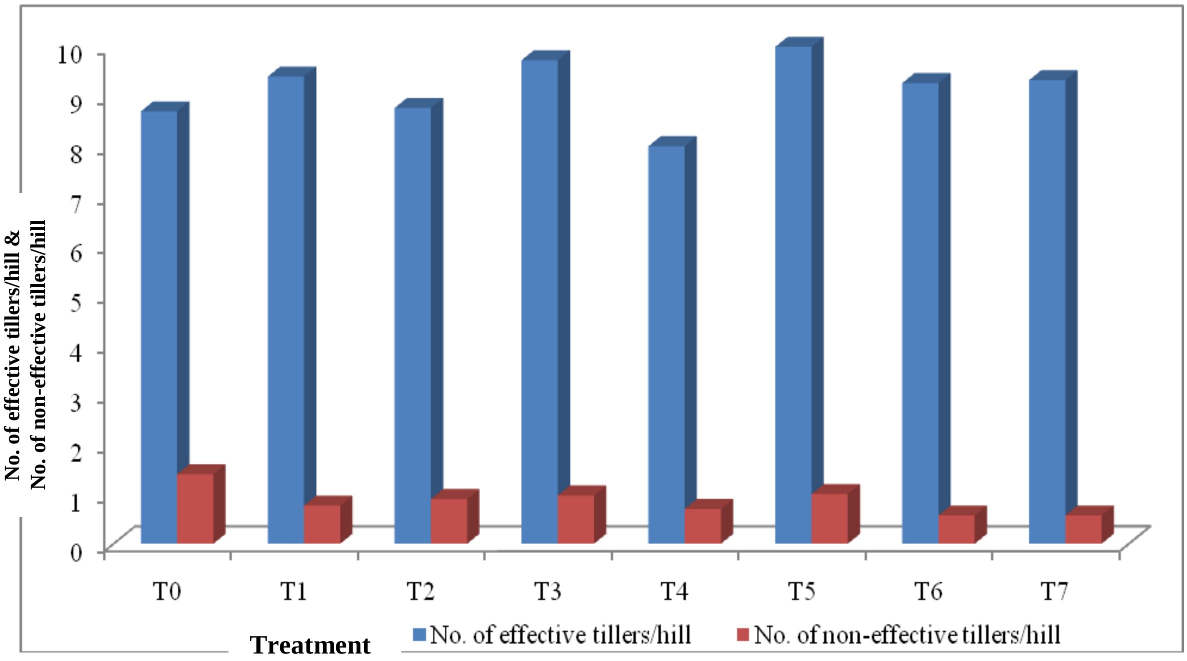

Figure 5: Effects of fertilizer and manure on effective tillers/hill & non- effective tillers/hill of T. Aman rice

4.1.3 Effects of combined use of fertilizer, manure and irrigation on the number of effective tillers/hill of T. Aman rice

The combined effect of different doses of fertilizer and irrigation on the number of effective tillers/hill of rice was insignificant (Table 4.3). The highest number of effective tillers/hill of rice (10.60) was recorded with the treatment combination I_1T_5 (Continuous flooding in combination with 70% NPKSZn + 3 ton compost/ha), which were similar to I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha), I_2T_3 (Saturated condition + 70% NPKSZn + 3 ton cowdung/ha) & I_1T_1 (Continuous flooding + 100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$) treatments. On the other hand, the lowest number of effective tillers/hill (7.67) was found in I_1T_4 (Continuous flooding in combination with 50% NPKSZn + 5 ton compost/ha).

Table 4.3 Effects of fertilizer and irrigation on effective tillers/hill and non-effective tillers/hill of T. Aman rice

Treatments	No. of effective tillers/hill	No. of non-effective tillers/hill
I_1T_0	8.27	1.27
I_1T_1	10.07	0.93
I_1T_2	8.73	1.00
I_1T_3	9.33	1.13
I_1T_4	7.67	0.73
I_1T_5	10.60	0.80
I_1T_6	10.27	0.80
I_1T_7	9.07	0.47
I_2T_0	9.13	1.53
I_2T_1	8.73	0.60
I_2T_2	8.80	0.80
I_2T_3	10.13	0.80
I_2T_4	8.33	0.67
I_2T_5	9.40	1.20
I_2T_6	8.27	0.33
I_2T_7	9.60	0.67
SE (±)	NS	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.2 Non-effective tiller

4.2.1 Effect of irrigation on the non-effective tillers/hill of T. Aman rice

The effect of irrigation on the non-effective tillers/hill of T. Aman rice are presented in (Table 4.1). Insignificant variation was observed on the non-effective tillers/hill of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_1 (Continuous flooding) showed the highest number of non-effective tillers/hill (0.89) and I_2 (Saturated condition) irrigation showed lowest number of non-effective tillers/hill (0.83).

4.2.2 Effects of fertilizer and manure on the non-effective tillers/hill of T. Aman rice

Different doses of fertilizers and manure showed significant variations on the number of non-effective tillers/hill of T. Aman rice (Table 4.2 & Figure: 5). Among the different doses of fertilizers, T_0 (Control) treatment showed the highest number of non-effective tillers/hill (1.4) which was statistically similar to T_5 (70% NPKSZn + 3 ton compost/ha) & T_3 (70% NPKSZn + 3 ton cowdung/ha) treatments. On the contrary, the lowest number of non-effective tillers/hill (0.57) were observed in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) & T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatments, which were statistically similar to T_1 (100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$), T_2 (50% NPKSZn + 5 ton cowdung/ha) & T_4 (50% NPKSZn + 5 ton compost/ha) & treatments.

4.2.3 Interaction effects of fertilizer, manure and irrigation on the number of non-effective tillers/hill of T. Aman rice

The combined effect of different doses of fertilizer and irrigation on the number of non-effective tillers/hill of T. Aman rice was insignificant (Table 4.3). The highest number of non-effective tillers/hill of rice (1.53) was recorded with the treatment combination I_2T_0 (Saturated condition + Control) which were similar to I_1T_0 (Continuous flooding + Control) & I_2T_5 (Saturated condition + 70% NPKSZn + 3 ton compost/ha) treatments. On the other hand, the lowest number of non-effective tillers/hill (0.33) was found in I_2T_6 (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure/ha) treatment which was similar to I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure/ha) treatment.

4.3 Plant height

4.3.1 Effect of irrigation on the plant height of T. Aman rice

The effects of irrigation on the plant height of rice are presented in (Table 4.4). Insignificant variation was observed on the plant height of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_2 (Saturated Condition) showed the highest plant height (110.47 cm) and I_1 (Continuous flooding) irrigation showed lowest plant height (109.89 cm).

Table 4.4 Effect of irrigation on the plant height and panicle length of T. Aman rice

Treatments (Irrigation)	Plant Height (cm)	Panicle Length (cm)
I_1	109.89	23.32
I_2	110.47	23.18
SE (±)	NS	NS

4.3.2 Effects of fertilizer and manure on the plant height of T. Aman rice

Rice plants showed significant variation in respect of plant height when fertilizers of different doses were applied (Table 4.5 & Figure 6). Among the different fertilizer doses, T_1 (100% Recommended dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$) showed the highest plant height (112.73 cm), which was closely followed by (112.53 cm) T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatment. On the other hand lowest plant height (101.72 cm) was observed in the T_0 treatment where no fertilizer was applied. Plant height was significantly influenced by the application of organic manure and chemical fertilizers reported by Nayak *et al*. (2007). Similar results also reported by Aga *et al*. (2004), Reddy *et al*. (2004).

Table 4.5 Effects of fertilizer and manure on the plant height and panicle length of T. Aman rice

Treatments	Plant Height (cm)	Panicle Length (cm)
T_0	101.72	22.04
T_1	112.73	23.82
T_2	111.35	23.62
T_3	112.42	23.45
T_4	112.48	23.54
T_5	110.45	23.43
T_6	107.78	22.47
T_7	112.53	23.65
SE (±)	NS	NS

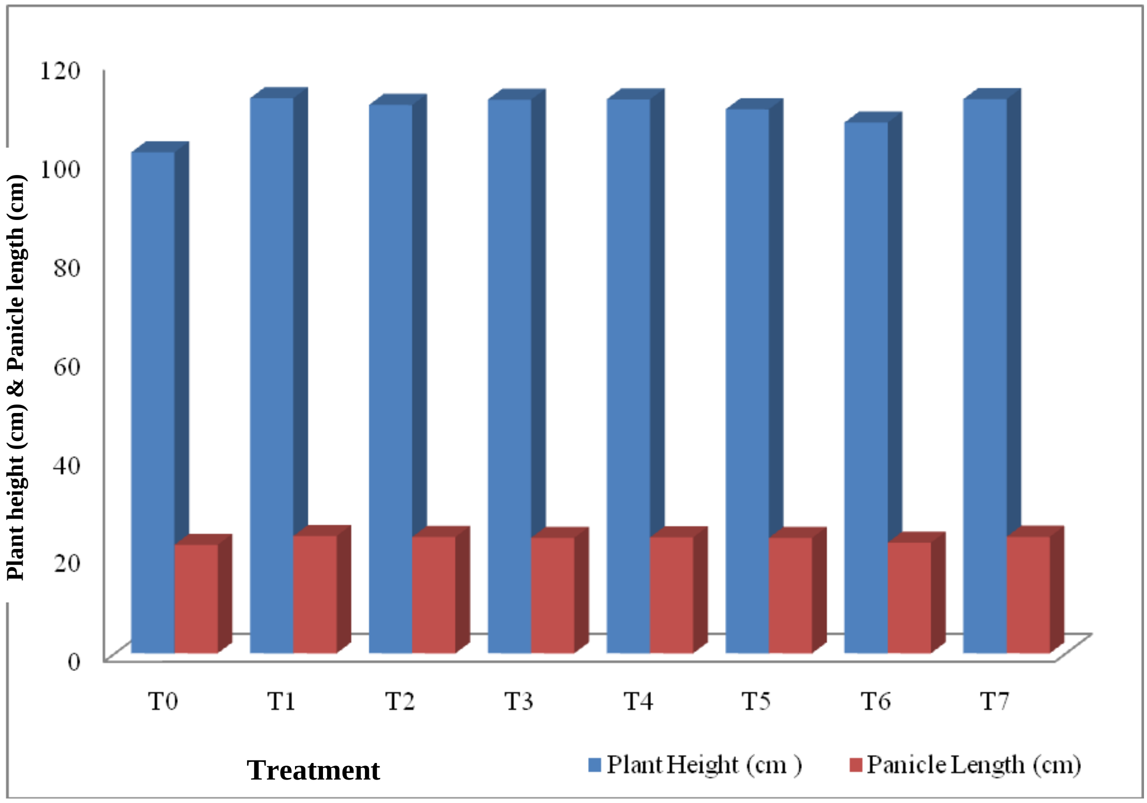

Figure 6: Effects of fertilizer and manure on plant height & panicle length of T. Aman rice

4.3.3 Effects of fertilizer and irrigation on the plant height of T. Aman rice

Combined application of different doses of fertilizer, manure and irrigation had insignificant variation on the plant height of T. Aman rice (Table 4.6). The lowest plant height (99.60 cm) was observed in the treatment combination of I_1T_0 (Continuous flooding + Control), which was similar to I_2T_0 (Saturated condition + Control) treatment. On the other hand, the highest plant height (115.63 cm) was recorded with I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure/ha) treatment. which was similar to I_1T_4 (Continuous flooding + 50% NPKSZn + 5 ton compost/ha), I_2T_1 (Saturated condition + 100% Recommended Dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$) & I_2T_3 (Saturated condition + 70% NPKSZn + 3 ton cowdung/ha) treatments.

Table 4.6 Interaction effects of fertilizer and irrigation on the plant height and panicle length of T. Aman rice

Treatments	Plant Height (cm)	Panicle Length (cm)
I_1T_0	99.60	22.19
I_1T_1	111.60	23.55
I_1T_2	109.73	23.28
I_1T_3	110.90	23.35
I_1T_4	113.20	24.29
I_1T_5	110.53	23.54
I_1T_6	107.97	22.12
I_1T_7	115.63	24.25
I_2T_0	103.83	21.89
I_2T_1	113.87	24.08
I_2T_2	112.97	23.97
I_2T_3	113.93	23.55
I_2T_4	111.77	22.78
I_2T_5	110.37	23.32
I_2T_6	107.60	22.82
I_2T_7	109.43	23.04
SE (±)	NS	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.4 Panicle length

4.4.1 Effect of irrigation on the panicle length of T. Aman rice

The effects of irrigation on the panicle length of T. Aman rice are presented in (Table 4.4). Insignificant variation was observed in the panicle length of rice when the field was irrigated with two different irrigations. Between this two irrigations, I_1 (continuous flooding) showed the highest panicle length (23.32 cm) and I_2 (Saturated Condition) irrigation showed lowest panicle length (23.18 cm).

4.4.2 Effects of different doses of fertilizer and manure on the panicle length of T. Aman rice

Rice plants showed insignificant variation in respect of panicle length when different doses of fertilizer and manures were applied (Table 4.5 & Figure: 6). Among the different fertilizer doses, T_1 (100% Recommended dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$) showed the highest panicle length (23.82 cm), which were similar to T_2 (50% NPKSZn + 5 ton cowdung/ha) & T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatments. On the other hand lowest panicle length (22.04 cm) was observed in the T_0 (Control) treatment where no fertilizer was applied, which was similar to T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment. Rahman *et al. (*2009) noted a significant increase in panicle length due to the application of organic manure and chemical fertilizers. Babu *et al*. (2001), Reddy *et al*. (2005) also reported similar results.

4.4.3 Effects of fertilizer and irrigation on the panicle length of T. Aman rice

Combined application of different doses of fertilizer and irrigation had insignificant variation on the panicle length of rice (Table 4.6). The lowest panicle length (21.89 cm) was observed in the treatment combination of I_2T_0 (Saturated Condition + No fertilizer) which were similar to I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha) and I_1T_0 (Continuous flooding + Control) treatments. On the other hand, the highest panicle length (24.29 cm) was recorded with I_1T_4 (Continuous flooding with 50% NPKSZn + 5 ton compost/ha) treatment which were similar to I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure/ha) and I_2T_1 (Saturated condition + 100% Recommended Dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$) treatments.

4.5 Number of filled grains per panicle

4.5.1 Effect of irrigation on the number of filled grains per panicle of T. Aman rice

The effects of irrigation on the number of filled grains per panicle of rice are presented in (Table 4.7). Insignificant variation was observed on the number of filled grains per panicle of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_1 (Continuous flooding)) showed the lowest number of filled grains per panicle (87.97) and I_2 (Saturated condition) showed highest number of filled grains per panicle (89.65).

4.7 Effect of irrigation on the no. of filled grains/panicle and 1000 grain wt. of rice

Treatments	No. of filled grains/panicle	1000 grain wt. (g)
I_1	87.97	21.18
I_2	89.65	21.29
SE (±)	NS	NS

4.5.2 Effects of fertilizer on the number of filled grains per panicle of T. Aman rice

Insignificant variation was observed in number of filled grains per panicle of T. Aman rice when different doses of fertilizer were applied (Table 4.8 Figure: 7). The highest number of filled grains per panicle (94.20) was recorded in T_1 (100% Recommended Dose $N_{120}P_{25}K_{60}S_{20}Zn_2$) treatment which was similar to T_2 (50% NPKSZn + 5 ton cowdung/ha) treatment. The lowest number of filled grain per panicle (79.47) was recorded in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment. Similar result was found by Rahman *et al.* (2009).

Table 4.8 Effects of fertilizer and manure on the no. of filled grains/panicle and 1000 grain wt. of T. Aman rice

Treatments	No. of filled grains/panicle	1000 grain wt. (g)
T_0	85.17	20.47 b
T_1	94.20	21.32 ab
T_2	93.78	21.20 ab
T_3	90.50	21.21 ab
T_4	88.98	21.11 ab
T_5	89.72	20.93 ab
T_6	79.47	21.90 a
T_7	88.68	21.72 a
SE (±)	NS	0.28

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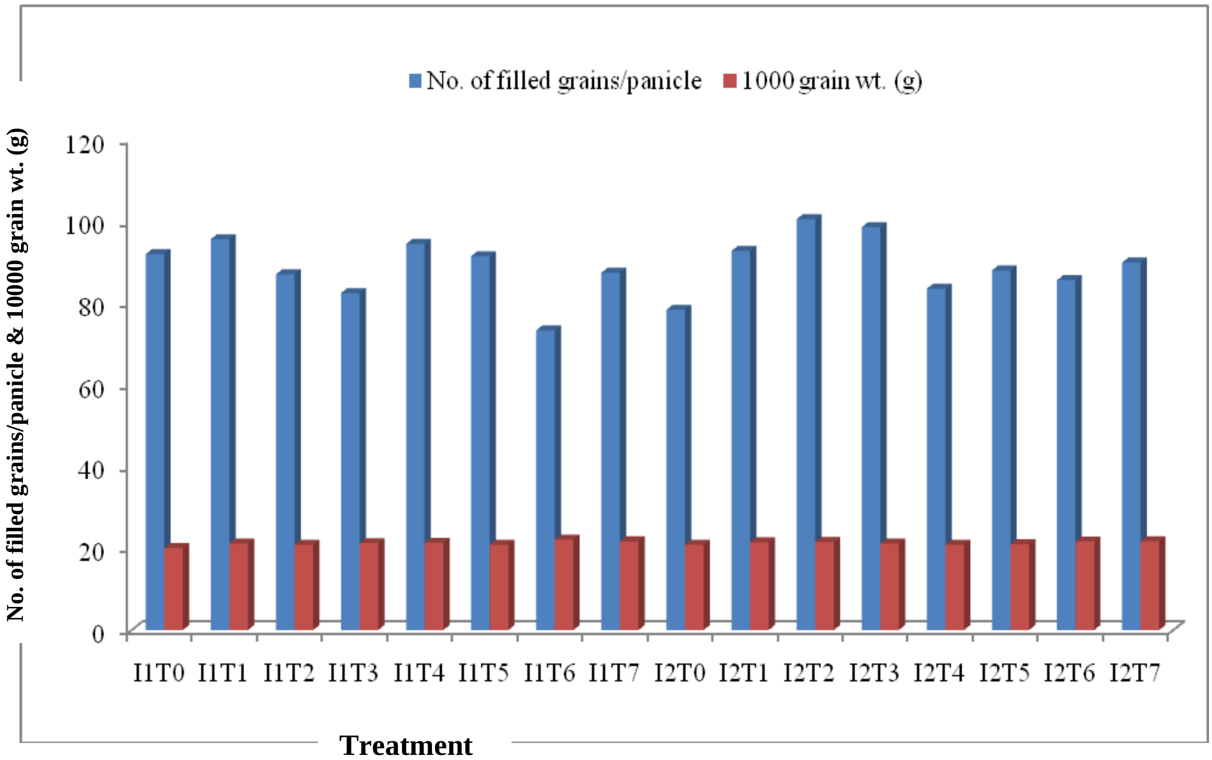

Figure 7: Effects of fertilizer and manure on No. of filled grains/panicle & 1000 grain wt. of T. Aman rice

4.5.3 Effects of fertilizer and irrigation on the number of filled grain per panicle of T. Aman rice

The combined effect of different doses of fertilizer and irrigation on the number of filled grains per panicle was insignificant (Table 4.9). The highest number of filled grain per panicle of rice (100.53) was recorded with the treatment combination I_2T_2 (saturated condition with 50% NPKSZn + 5 ton cowdung/ha) treatment. On the other hand, the lowest number of filled grain (73.33) was found in I_1T_6 (continuous flooding with 50% NPKSZn + 3.5 ton poultry manure/ha) treatment combination.

Table 4.9 Interaction effects of fertilizer and irrigation on the no. of filled grains/panicle and 1000 grain wt. of T. Aman rice

Treatments	No. of filled grains/panicle	1000 grain wt. (g)
I_1T_0	91.97	20.05
I_1T_1	95.63	21.17
I_1T_2	87.03	20.86
I_1T_3	82.43	21.28
I_1T_4	94.47	21.35
I_1T_5	91.47	20.87
I_1T_6	73.33	22.12
I_1T_7	87.43	21.71
I_2T_0	78.37	20.88
I_2T_1	92.77	21.47
I_2T_2	100.53	21.55
I_2T_3	98.57	21.14
I_2T_4	83.50	20.86
I_2T_5	87.97	20.99
I_2T_6	85.60	21.68
I_2T_7	89.93	21.73
SE (±)	NS	NS

4.6 1000-grain wt. of T. Aman rice

4.6.1 Effect of irrigation on the 1000-grain wt. of T. Aman rice

The effects of irrigation on the 1000 grain wt. of T. Aman rice are presented in (Table 4.7). Insignificant variation was observed on the 1000-grain wt. of T. Aman rice when the field was irrigated with two different irrigations. Between these two irrigations, I_2 (Saturated condition) showed the highest 1000-grain wt. (21.29 g) and I_1 (continuous flooding) irrigation showed lowest 1000-grain wt. (21.18 g).

4.6.2 Effects of fertilizer and manure on the 1000 grain wt. of T. Aman rice

Rice plants showed significant variation in respect of 1000-grain wt. of rice when fertilizers of different doses were applied (Table 4.8 & Figure: 7). Among the different fertilizer doses, T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) showed the highest 1000-grain wt. (21.90 g) which was statistically comparable to all other treatments except to T_0 (Control) treatment. On the other hand, the lowest 1000 grain wt. (20.47 g) was observed in the T_0 (Control) treatment where no fertilizer was applied. Yang *et al.* (2004) also recorded that 1000 grain weight were increased by the application of chemical fertilizer with organic manure. Statistically similar thousand grain weight was observed in maximum treatments.

4.6.3 Interaction effects of fertilizer and irrigation on the 1000 grain wt. of T. Aman rice

The combined effect of different doses of fertilizer and irrigation on the 1000 grain wt. of T. Aman rice was insignificant (Table 4.9). The highest 1000 grain wt. of T. Aman rice (22.12 g) was recorded with the treatment combination I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha) which was similar to I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure/ha), I_2T_6 (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure/ha) & I_2T_7 (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure/ha) treatments. On the other hand, the lowest 1000 grain wt. (20.05 g) was found in I_1T_0 (Continuous flooding + control treatment) treatment combination which was similar to I_1T_2 (Continuous flooding + 50% NPKSZn + 5 ton cowdung/ha), I_1T_5 (Continuous flooding + 70% NPKSZn + 3 ton compost/ha), I_2T_0 (Saturated condition + Control) & I_2T_4 (Saturated condition + 50% NPKSZn + 5 ton compost/ha) treatments.

4.7 Grain yield

4.7.1 Effect of irrigation on the grain yield of T. Aman rice

The effects of irrigation on the grain yield of T. Aman rice are presented in (Table 4.10). Insignificant variation was observed on the grain yield of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_1 (Continuous flooding) showed the lowest grain yield (4.31ton/ha) and I_2 (saturated condition) irrigation showed highest grain yield (4.42 ton/ha).

Table 4.10 Effect of irrigation on the grain yield (ton/ha) and straw yield (ton/ha) of T. Aman rice

Treatments	Grain yield (ton/ha)	Straw yield (ton/ha)
I_1	4.31	6.01
I_2	4.42	5.93
SE (±)	NS	NS

4.7.2 Effects of different doses fertilizer and manure on the grain yield of T. Aman rice

Different doses of fertilizers showed significant variations in respect of grain yield (ton/ha) (Table 4.11 & Figure: 8). The application of fertilizers and manure had a positive effect on the grain yield of T. Aman rice. The yield increase varied from 23.91% to 36.15% and lowest yield increase was observed in T_1 (Recommended chemical fertilizer) treatment. The higher levels of % grain yield increase were observed in the integrated use of fertilizer and manure compared to chemical fertilizer alone. Among the different doses of fertilizers, T_4 (50% NPKSZn + 5 ton compost/ha) showed the highest grain yield (4.70 t/ha) which was statistically similar with T_1 (100% Recommended Dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$), T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) & T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatments. On the contrary, the lowest grain yield (3.43 ton/ha) was observed with T_0 treatment where no fertilizer was applied. The higher grain yield was found in the treatments where organic plus inorganic fertilizers were used. The yield decreased in order of T_4 (50% NPKSZn + 5 ton compost/ha) › T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) › T_6 (50% NPKSZn + 3.5 ton poultry manure/ha). Rahman *et al.* (2009) reported the grain yield was significantly increased due to application of organic manure and chemical fertilizers. This is also in agreement with the findings of Miah *et al*. (2006), Miah *et al*. (2004).

Table 4.11 Effects of fertilizer and manure on the grain yield & straw yield of T. Aman rice

Treatments	Grain yield (ton/ha)	Straw yield (ton/ha)
T_0	3.43 b	4.22 b
T_1	4.45 a	6.28 a
T_2	4.39 ab	5.89 a
T_3	4.34 ab	6.26 a
T_4	4.70 a	6.35 a
T_5	4.25 ab	5.89 a
T_6	4.66 a	6.58 a
T_7	4.67 a	6.28 a
SE (±)	0.269	0.272

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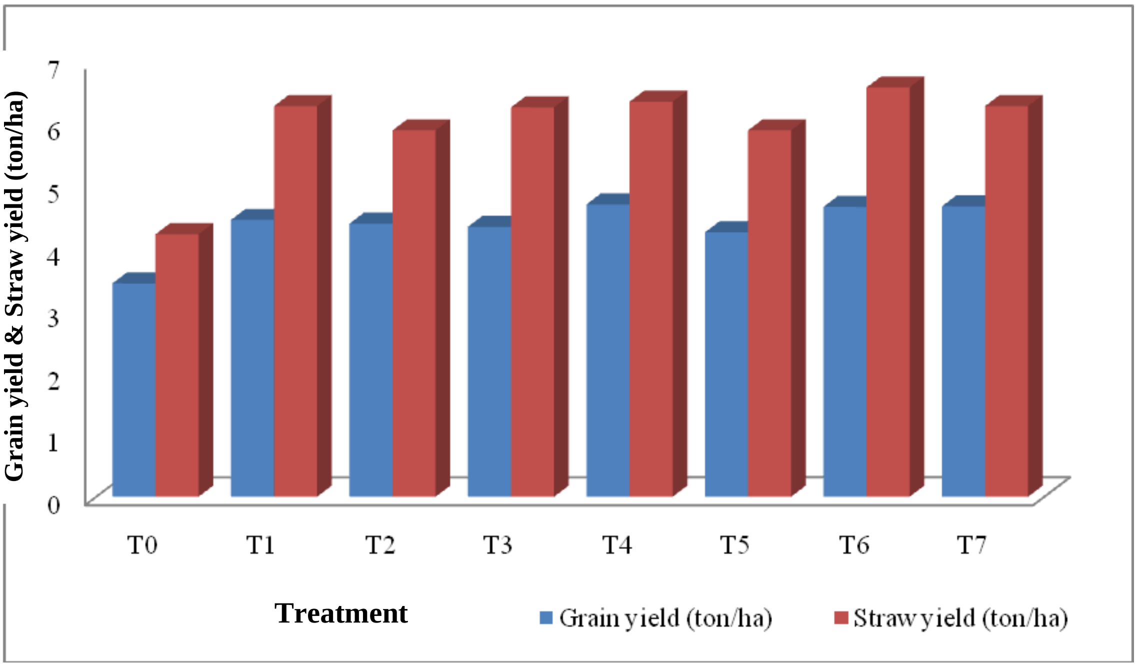

Figure 8: Effects of fertilizer and manure on grain yield & starw yield of T. Aman rice

4.7.3 Interaction effects of fertilizer and irrigation on the grain yield of T. Aman rice

The combined effect of different doses of fertilizer and irrigation on the grain yield of T. Aman rice was not significantly different (Table 4.12). The highest grain yield of T. Aman rice (4.87 ton/ha) was recorded with the treatment combination I_2T_4 (Saturated condition + 50% NPKSZn + 5 ton compost/ha), which was similar to I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure/ha) treatment. On the other hand, the lowest grain yield (3.07 ton/ha) was found in I_1T_0 (Continuous flooding + control) treatment combination. Lin *et al*. (2011) reported that irrigation with organic material application increased yield of rice.

Table 4.12 Interaction effects of fertilizer and irrigation on the grain yield and straw yield of T. Aman rice

Treatments	Grain yield (ton/ha)	Straw yield (ton/ha)
I_1T_0	3.07	4.04
I_1T_1	4.45	6.47
I_1T_2	4.53	5.95
I_1T_3	4.21	6.46
I_1T_4	4.54	6.43
I_1T_5	4.24	5.65
I_1T_6	4.68	6.69
I_1T_7	4.72	6.43
I_2T_0	3.79	4.41
I_2T_1	4.45	6.09
I_2T_2	4.24	5.85
I_2T_3	4.47	6.06
I_2T_4	4.87	6.28
I_2T_5	4.26	6.14
I_2T_6	4.65	6.47
I_2T_7	4.62	6.13
SE (±)	NS	NS

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4.8 Straw yield

4.8.1 Effect of irrigation on the straw yield of T. Aman rice

The effects of irrigation on the straw yield of T. Aman rice are presented in (Table 4.10). Insignificant variation was observed in the straw yield of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_1 (Continuous flooding) showed the highest straw yield (6.01 ton/ha) and I_2 (saturated condition) showed lowest straw yield (5.93 ton/ha).

4.8.2 Effects of different doses of fertilizer and manure on the straw yield of T. Aman rice

Significant variation was observed in the straw yield of T. Aman rice when different doses of fertilizer were applied (Table 4.11 & Figure: 8). The highest yield of straw (6.58 ton/ha) was recorded in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment which was statistically similar to T_1 (100% Recommended dose $N_{120}P_{25}K_{60}S_{20}Zn_2$), T_2 (50% NPKSZn + 5 ton cowdung/ha), T_3 (70% NPKSZn + 3 ton cowdung/ha), T_4 (50% NPKSZn + 5 ton compost/ha), T_5 (70% NPKSZn + 3 ton compost/ha), T_7 (0% NPKSZn + 2.1 ton poultry manure/ha) treatments. The lowest straw yield (4.22 ton/ha) was recorded in the T_0 treatment where no fertilizer was applied.

The straw yield increased from 40% to 56% and the highest level of straw yield increase was found in the T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment where mixture of chemical & organic fertilizer was used. Rahman *et al.* (2009) reported that the application of organic manure and chemical fertilizers increased the straw yields of rice. These findings are corroborated with the work of Mannan *et al.* (2000). It is clear that organic manure in combination with inorganic fertilizers vegetative growth of plants and thereby increased straw yield of rice.

4.8.3 Effects of fertilizer and irrigation on the straw yield of T. Aman rice

The combined effect of different doses of fertilizer and irrigation on the straw yield of T. Aman rice was insignificant (Table 4.12). The highest straw yield of rice (6.69 t/ha) was recorded with the treatment combination I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha), which were similar to I_1T_1 (Continuous flooding + 100% Recommended Dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$), I_1T_3 (Continuous flooding + 70% NPKSZn + 3 ton cowdung/ha) & I_2T_6 (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure/ha) treatments. On the other hand, the lowest straw yield (4.04 t/ha) was found in I_1T_0 (Continuous flooding + control) treatment combination, which was similar to I_2T_0 (Saturated condition + Control) treatment.

4.9 N, P and K concentration of pore-water in T. Aman rice

4.9.1 Effect of irrigation on the N, P and K concentration of pore-water during T. Aman rice growing period

The pore-water N, P and K concentrations were not significantly influenced by different irrigation management in the T. Aman rice field. There was no significant influence of irrigation on the pore-water N concentrations. Higher levels of pore-water N were found in the I_2 (Saturated condition) of rice plant & lower levels of pore-water N were found in the I_1 (Continuous flooding) condition.

There was no significant influence of irrigation on the pore-water P concentrations and higher levels of pore-water P were found in the I_2 (Saturated condition) of rice plant compared to I_1 (Continuous flooding) condition.

The pore-water K concentrations were influenced by different irrigation management in the T. Aman rice field. The higher pore-water K concentration was found in I_1 (Continuous flooding) condition and lower in I_2 (Saturated condition).

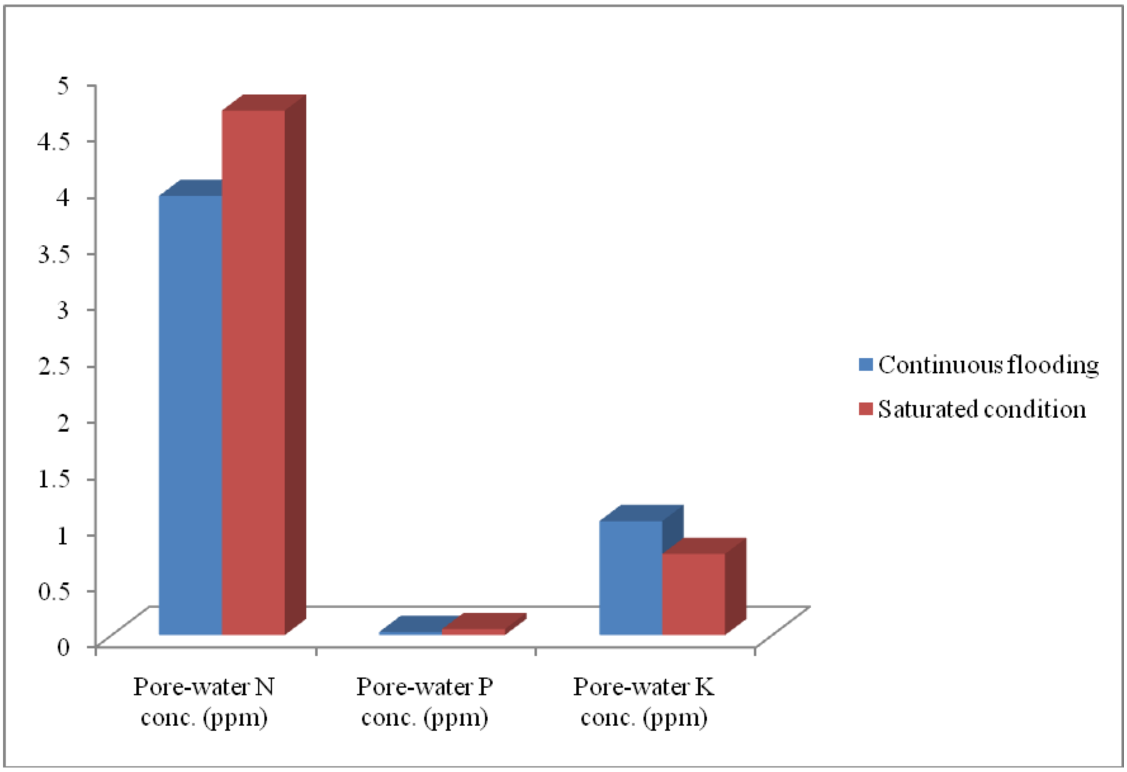

Figure 9: Effect of irrigation on the N, P & K concentrations in the pore water of root zone area

4.9.2 Effects of fertilizer and manure on the pore-water N, P & K concentrations

The levels of pore-water N concentrations were not significantly influenced by manure and fertilizer application. Among the fertilizer treatments, the higher pore-water N concentrations were recorded in T_1 (100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$) & T_5 (70% NPKSZn + 3 ton compost/ha) treatments, which were similar to T_4 (50% NPKSZn + 5 ton compost/ha) & T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatments. The lowest pore-water N concentration was found in the T_0 (control) treatment where fertilizer was not used.

The levels of pore-water P concentrations were not significantly influenced by manure and fertilizer application. Among the fertilizer treatments, the higher pore-water P concentrations were recorded in T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatment. The lowest pore-water P concentration was found in the T_0 (control) treatment where fertilizer was not used, which was similar to T_4 (50% NPKSZn + 5 ton compost/ha) treatment.

The levels of pore-water K concentrations were not significantly influenced by manure and fertilizer application. Among the fertilizer treatments, the highest pore-water K concentration was recorded in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment. The lowest pore-water K concentration was found in the T_0 (control) treatment where fertilizer was not used, which was similar to T_1 (100% Recommended Dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$) treatment.

Table 4.13: Effects of fertilizer and manure on the pore-water N, P & K concentration in the rice root zone area

Treatment	Pore-water N conc. (ppm)	Pore-water P conc. (ppm)	Pore-water K conc. (ppm)
T_0	3.48	0.012	0.500
T_1	4.55	0.025	0.556
T_2	4.20	0.051	0.778
T_3	4.14	0.035	0.778
T_4	4.32	0.014	0.833
T_5	4.55	0.048	1.111
T_6	4.21	0.039	1.500
T_7	4.38	0.097	0.889
SE (±)	NS	NS	NS

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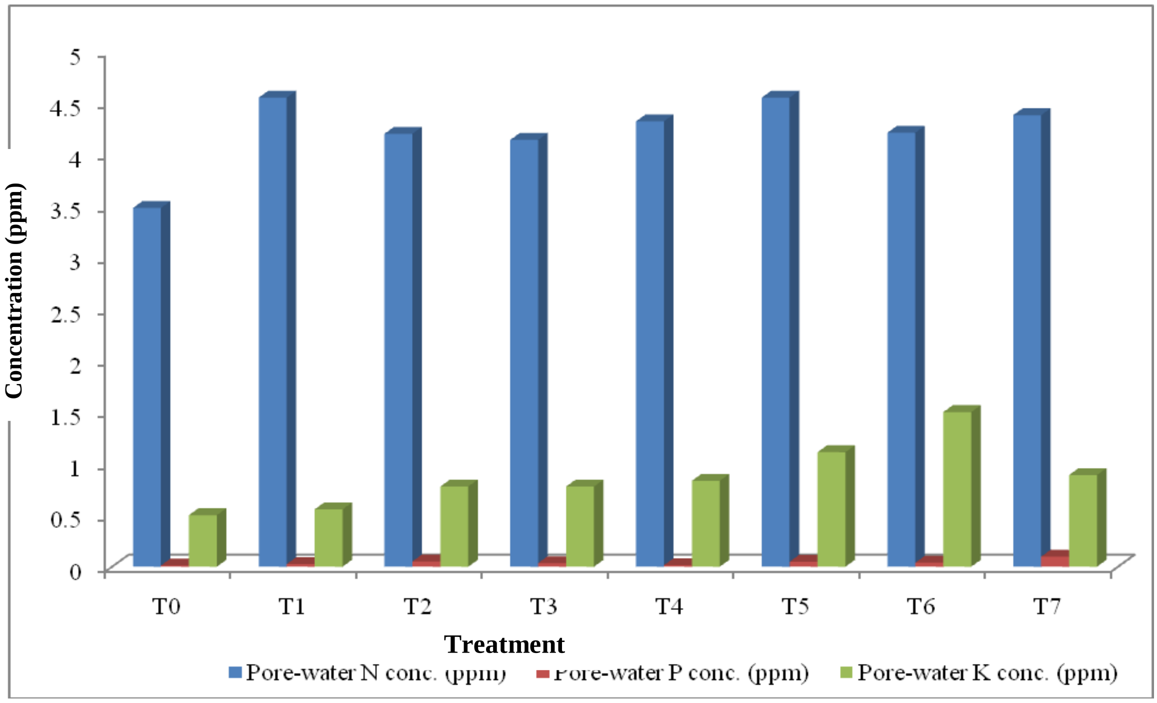

Figure 10: Effects of fertilizer and manure on the pore-water N, P & K conc. in the rice root zone area

4.9.3 Combined effects of irrigation and fertilizer on the pore-water N, P & K concentration

The pore-water N concentrations were not significantly different by combined application of different levels of fertilizer and irrigation. The higher pore-water N concentrations were found in I_2T_1 (Saturated condition + 100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$) & I_2T_2 (Saturated condition + 50% NPKSZn + 5 ton cowdung/ha) treatments, which was similar to I_2T_7 (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure/ha) treatment. On the other hand the lower pore-water N concentrations was found in I_1T_0 (Continuous flooding + Control) treatment, which was similar to I_1T_2 (Continuous flooding + 50% NPKSZn + 5 ton cowdung/ha) treatment.

The higher levels of P concentrations were found in the pore-water samples of rice root zone area where organic plus inorganic fertilizers were applied combindly. Higher levels of P concentrations were found in I_2T_7 (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure/ha) treatment. Lower levels of P concentrations were found in I_1T_0 (Continuous flooding + Control), I_1T_3 (Continuous flooding + 70% NPKSZn + 3 ton cowdung/ha), I_2T_0 (Saturated condition + Control), I_2T_4 (Saturated condition + 50% NPKSZn + 5 ton compost/ha) treatments.

The pore-water K concentrations were not significantly different by combined application of different levels of fertilizer and irrigation. The higher pore-water K concentrations were found in I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha) treatments. The Lower pore-water K concentrations were found in I_1T_0 (Continuous flooding + Control), I_1T_2 (Continuous flooding + 50% NPKSZn + 5 ton cowdung/ha), I_2T_1 (Saturated condition + 100% Recommended Dose, $N_{120}P_{25}K_{60}S_{20}Zn_2$) treatments.

Table 4.14 Combined effects of fertilizer and irrigation on the N, P & K concentrations in the pore-water of T. Aman rice growing period

Treatments	Pore-water N conc. (ppm)	Pore-water P conc. (ppm)	Pore-water K conc. (ppm)
I_1T_0	3.37	0.012	0.444
I_1T_1	4.08	0.016	0.667
I_1T_2	3.38	0.058	0.444
I_1T_3	3.96	0.012	0.889
I_1T_4	3.85	0.016	0.666
I_1T_5	4.31	0.050	1.556
I_1T_6	3.97	0.029	2.333
I_1T_7	3.85	0.021	1.111
I_2T_0	4.08	0.012	0.556
I_2T_1	5.01	0.033	0.444
I_2T_2	5.01	0.044	1.111
I_2T_3	4.31	0.058	0.667
I_2T_4	4.78	0.012	1.000
I_2T_5	4.78	0.045	0.667
I_2T_6	4.45	0.050	0.667
I_2T_7	4.90	0.173	0.667
SE (±)	NS	NS	NS

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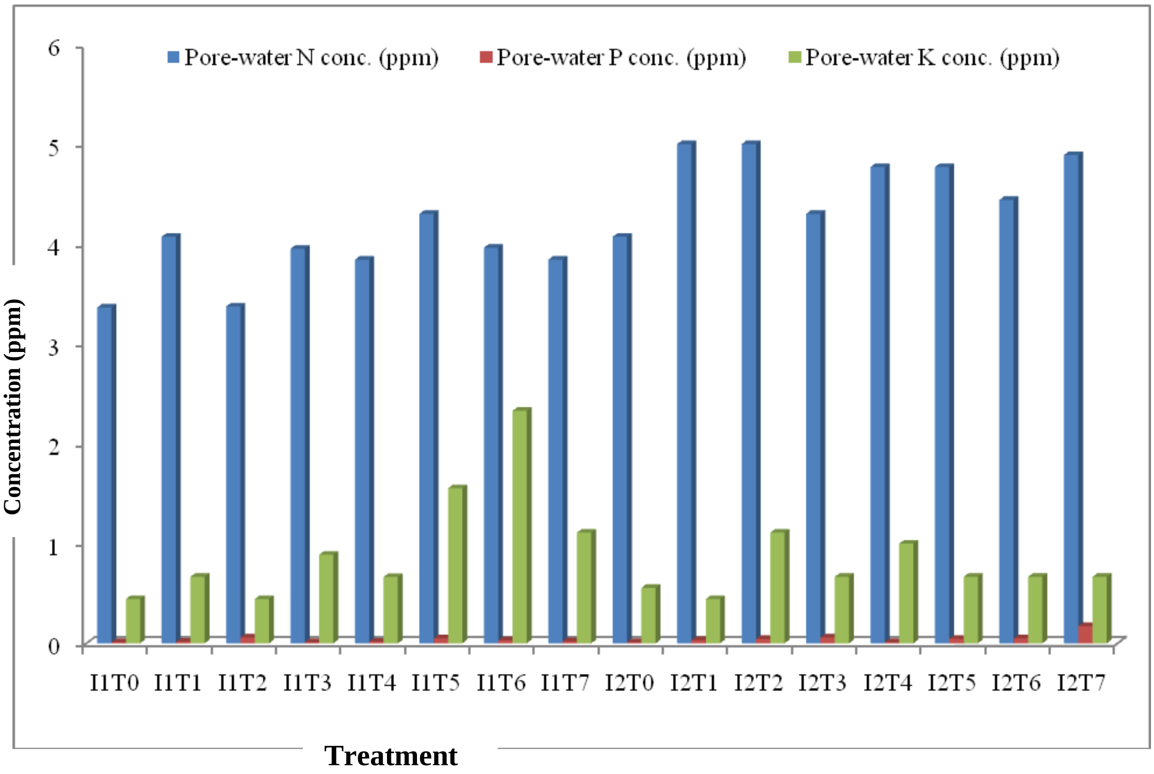

Figure 11: Effects of fertilizer and irrigation on the N, P & K concentrations in the pore-water of T. Aman rice growing period

4.10 N, P & K concentration in T. Aman rice grain

4.10.1 Effect of irrigation on N, P & K concentration in T. Aman rice grain

The effects of irrigation on N concentration in grain of T. Aman rice are presented in Figure 17. Insignificant variation was observed on N concentration in grain of T. Aman rice when the field was irrigated with two different irrigations. Between these two irrigations I_1 (Continuous flooding) irrigation showed the highest N concentration in grain (1.3 %) and I_2 (Saturated condition) showed the lowest N concentration in grain (1.21 %).

Insignificant variation was observed on P concentration in grain of T. Aman rice when the field was irrigated with two different irrigations. Between these two irrigations, I_1 (Continuous flooding) showed the highest (0.228 %) P concentration in grain and I_2 (Saturated condition) irrigation showed the lowest (0.207 %) P concentration in grain.

Insignificant variation was observed on K concentration in grain of rice when the field was irrigated with two different irrigations. Between these two irrigations, I_2 (Saturated condition) showed the highest K concentration (0.257 %) in grain and I_1 (Continuous flooding) irrigation showed the lowest K concentration (0.256%) in grain.

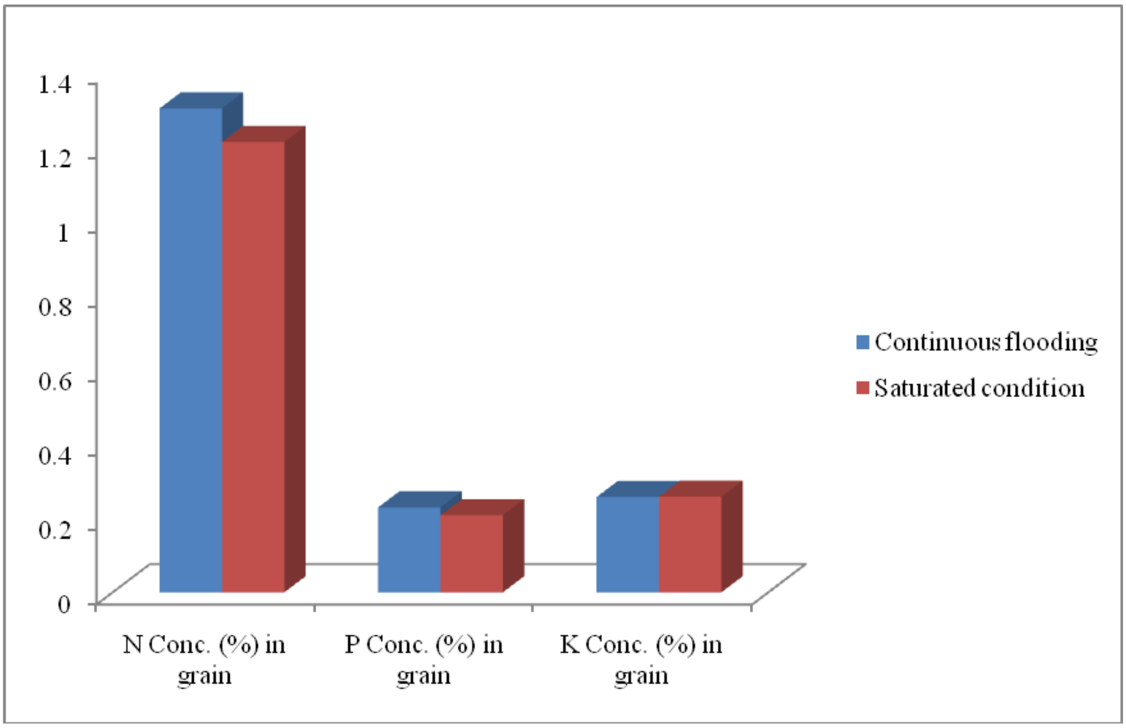

Figure 12: Effect of irrigation on N, P & K concentration in T. Aman rice grain

4.10.2 Effects of fertilizer and manure on N, P & K concentration in T. Aman rice grain

Nitrogen concentrations in grain of T. Aman rice showed statistically significant due to the application of different doses of fertilizer & manure are presented in Table 4.17. The highest level of N concentration in grain (1.280 %) was recorded in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment, which were statistically compareable to T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) & T_1 (100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$) treatments. On the other hand, the lowest level of N concentration in grain (1.063 %) was found in T_0 (Control) treatment which was statistically compareable to (1.095 %) by T_4 (50% NPKSZn + 5 ton compost/ha) treatment. A significant increase in N content in rice grain due to the application of organic manure and fertilizers have been reported by investigators (Azim, 1999 and Haque, 1999).

Phosphorous concentrations in grain of rice showed statistically significant variation due to the application of different doses of fertilizer & manure. The highest P concentration in grain (0.262 %) was recorded from T_3 (70% NPKSZn + 3 ton cowdung/ha) treatment. On the other hand, the lowest P concentration in grain (0.174 %) was found from T_0 (Control) treatment. A significant increase in P content in rice grain due to the application of organic manure and fertilizers has been reported by investigators (Azim, 1999 and Haque, 1999).

Potassium concentrations in grain of T. Aman rice showed statistically significant variation due to the application of different doses of fertilizer & manure. The highest K concentration in grain (0.282%) was recorded from T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment, which were statistically compareable to T_2 (50% NPKSZn + 5 ton cowdung/ha), T_4 (50% NPKSZn + 5 ton compost/ha) & T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatments. The combined application of fertilizer and manure increased the K accumulation in rice grain. On the other hand, the lowest K concentration in grain (0.206 %) was found in T_0 (Control) treatment, which was statistically compareable to T_5 (70% NPKSZn + 3 ton compost/ha) treatment. Singh *et al.* (2001) revealed that Potassium content in grains was increased due to combined application of organic manure and chemical fertilizers.

Table 4.15. Effects of fertilizer and manure on N, P & K concentration in T. Aman rice grain

Treatments	**Concentration (%) in grain**		
	N	**P**	**K**
T_0	1.063 c	0.174 f	0.206 b
T_1	1.215 a	0.238 b	0.249 ab
T_2	1.185 ab	0.230 c	0.281 a
T_3	1.185 ab	0.262 a	0.248 ab
T_4	1.095 bc	0.232 c	0.280 a
T_5	1.185 ab	0.226 d	0.219 b
T_6	1.280 a	0.241 b	0.282 a
T_7	1.220 a	0.217 e	0.281 a
SE (±)	0.032	0.007	0.013

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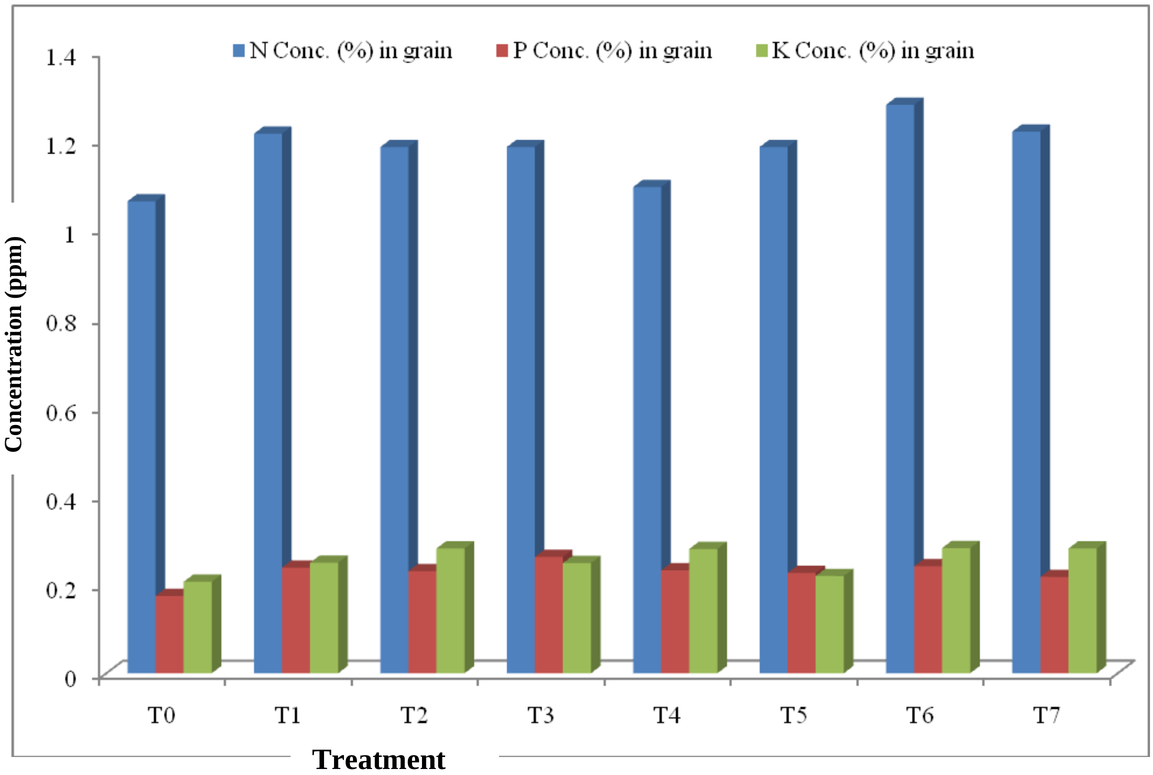

Figure 13: Effects of fertilizer and manure on N, P & K concentration in T. Aman rice grain

There were no significant variations found for the N, P & K concentrations in grain with combined effect of irrigation and fertilizers.

CHAPTER-5

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2013 to November 2013 to study the effect of various organic manure and inorganic fertilizer with different water management on the growth and yield of T. Aman rice. BRRI dhan 32 was used as the test crop in this experiment. The experiment consists of 2 factors i.e. irrigation and fertilizer plus manure. Two levels of irrigations (I_1 = Continuous flooding and I_2 = Saturated condition) were used with 8 levels of fertilizer plus manure, as T_0: Control, T_1: 100% $N_{120}P_{25}K_{60}S_{20}Zn_2$ (Recommended dose), T_2: 50% NPKSZn + 5 ton cowdung/ha, T_3: 70% NPKSZn + 3 ton cowdung/ha, T_4: 50% NPKSZn + 5 ton compost/ha, T_5: 70% NPKSZn + 3 ton compost/ha, T_6: 50% NPKSZn + 3.5 ton poultry manure/ha and T_7: 70% NPKSZn + 2.1 ton poultry manure/ha, with 16 treatment combination as I_1T_0 = (Continuous flooding + Control), I_1T_1 = (Continuous flooding + 100% $N_{120}P_{25}K_{60}S_{20}Zn_2$; Recommended dose), I_1T_2 = (Continuous flooding + 50% NPKSZn + 5 ton cowdung/ha), I_1T_3 = (Continuous flooding + 70% NPKSZn + 3 ton cowdung/ha), I_1T_4 =(Continuous flooding + 50% NPKSZn + 5 ton compost/ha), I_1T_5 = (Continuous flooding + 70% NPKSZn + 3 ton compost/ha), I_1T_6 = (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha), I_1T_7 = (Continuous flooding + 70% NPKSZn +2.1 ton poultry manure/ha), I_2T_0 = (Saturated condition + Control), I_2T_1 = (Saturated condition + 100% $N_{120}P_{25}K_{60}S_{20}Zn_2$; Recommended dose), I_2T_2 = (Saturated condition + 50% NPKSZn + 5 ton cowdung/ha), I_2T_3 = (Saturated condition + 70% NPKSZn + 3 ton cowdung/ha), I_2T_4 = (Saturated condition + 50% NPKSZn + 5 ton compost/ha), I_2T_5 = (Saturated condition + 70% NPKSZn + 3 ton compost/ha), I_2T_6 = (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure/ha), I_2T_7 = (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure/ha), and 3 replications R_1, R_2, R_3. The total number of effective tillers/hill, non-effective tillers/hill, plant height, panicle length, number of filled grains/panicle, 1000 grain weight, grain yield and straw yield were not significantly affected by single effect of irrigation. The highest number of effective tillers/hill, non-effective tillers/hill, panicle length and straw yield were observed from I_1 (Continuous flooding) treatment and the highest plant height, number of filled grains/panicle, 1000-grain weight and grain yield were observed from I_2 (Saturated condition) treatment.

Yield contributing characters and yields were significantly affected by fertilizer and manure. The highest effective tillers/hill (10.00), non-effective tillers/hill (1.40), plant height (112.73 cm), panicle length (23.82 cm), No. of filled grains/panicle (94.20), 1000 grain weight (21.90 g), grain yield (4.70 t/ha) and straw yield (6.58 t/ha) were found from T_5 (70% NPKSZn + 3 ton compost/ha), T_0 (Control), T_1 (100% $N_{120}P_{25}K_{60}S_{20}Zn_2$; Recommended dose), T_1 (100% $N_{120}P_{25}K_{60}S_{20}Zn_2$; Recommended dose), T_1 (100% $N_{120}P_{25}K_{60}S_{20}Zn_2$; Recommended dose), T_6 (50% NPKSZn + 3.5 ton poultry manure/ha), T_4 (50% NPKSZn + 5 ton compost/ha) and T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatments respectively and lowest in T_0 (Control) treatment except to No. of effective tiller/hill, No. of non-effective tillers/hill & No. of filled grains/panicle. The grain yield of different fertilizer treatments followed the order of $T_4 > T_7 > T_6 > T_1 > T_2 > T_3 > T_5 > T_0$. The highest values of effective tillers/hill (10.60), grain yield (4.87 t/ha) and straw yield (6.69 t/ha) were recorded from I_1T_5 (Continuous flooding + 70% NPKSZn + 3 ton compost/ha), I_2T_4 (Saturated condition + 50% NPKSZn + 5 ton compost/ha) and I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha) treatments combination respectively. The lowest values of effective tillers/hill (7.67) was observed from I_1T_4 (Continuous flooding + 50% NPKSZn + 5 ton compost/ha) treatment combination. The lowest panicle length (21.89 cm) was observed from I_2T_0 (Saturated condition + Control) treatment combination. The lowest plant height (99.60 cm), grain yield (3.07 t/ha), straw yield (4.04 t/ha) were observed from I_1T_0 (Continuous flooding + Control) treatment combination.

The N, P and K concentrations were studied in the pore-water & these were insignificantly affected by application of irrigation. The concentrations of N, P and K were varied with the application of irrigation & fertilizer. The higher levels of pore-water N and P concentrations were recorded from I_2 (Saturated condition) and K concentrations were recorded from I_1 (Continuous flooding) treatment. The higher concentration of pore water N was found in the T_1 (100% Recommended Dose; $N_{120}P_{25}K_{60}S_{20}Zn_2$) & T_5 (70% NPKSZn + 3 ton compost/ha) treatments. The higher concentration of pore water P and K were found in the T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) and T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatments respectively.

The combined effect of irrigation and fertilizer were insignificantly influenced the N, P & K concentrations of pore-water and higher levels N concentrations were observed in I_2T_1 (Saturated condition + 100% Recommended Dose ($N_{120}P_{25}K_{60}S_{20}Zn_2$) & I_2T_2 (Saturated condition + 50% NPKSZn + 5 ton cowdung/ha) treatments. Higher levels P & K concentrations were observed in I_2T_7 (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure/ha) & I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure/ha) treatment combinations.

The nutrient concentration in T. Aman rice grain was insignificantly affected by application of irrigation. The higher levels of grain N & P concentrations were recorded from I_1 (Continuous flooding), and K concentration was recorded from I_2 (Saturated condition) treatment. The nutrient concentration in T. Aman rice grain was significantly affected by application of fertilizer and manure. The highest concentrations of grain N (1.280 %), P (0.262 %) & K (0.282 %) were recorded from T_6 (50% NPKSZn + 3.5 ton poultry manure/ha), T_3 (70% NPKSZn + 3 ton cowdung/ha) & T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatments respectively and in all cases lowest value was observed in T_0 (Control) treatment. There were no significant variations found for the N, P & K concentrations in grain with combined effect of irrigation and fertilizers.

From the above discussion it can be concluded that irrigation had no significant effect on yield and yield contributing characters and Saturated condition is preferable than continuous flooding irrigation. The application of inorganic fertilizer plus manure performed better compared to inorganic fertilizer. The application of 70% NPKSZn + 2.1 ton poultry manure/ha and Saturated condition was most favorable for improving yield and yield contributing characters of T. Aman (BRRI dhan 32).

Before recommend findings of the present study, the following recommendations and suggestions may be made:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. Another combination of NPK and others organic manures with different water management may be included for further study.

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APPENDICES

Appendix- I: Particulars of the Agro-ecological Zone of the Experimental site

Agro-ecological region	Madhupur Tract (AEZ-28)
Land Type	Medium high land
General soil type	Non- Calcareous Dark gray floodplain soil
Soil series	Tejgaon
Topography	Up land
Location	SAU Farm, Dhaka
Field level	Above flood level
Drainage	Fairly good
Firmness(consistency)	Compact to friable when dry

Appendix - II : Monthly mean weather

AppendixII. Records of meteorological information (monthly) during the period from June, 2013 to December, 2013

Name of the Months	Average Air temp ^{0}C (^{0}F)		Relative humidity (%)	Rainfall/Precipitation mm (inches)
	Maximum	Minimum		
June, 2013	32.1 (89.8)	26.1 (79)	72	340.4 (13.402)
July, 2013	31.4 (88.5)	26.2 (79.2)	72	373.1 (14.689)
August, 2013	31.1 (88.0)	26.1 (79.0)	73	342.5 (13.484)
September, 2013	30.8 (87.4)	25.8 (78.4)	74	262.4 (10.331)
October, 2013	30.5 (86.9)	22.3 (72.1)	63	135.4 (5.331)
November, 2013	28.5 (83.3)	18.5 (65.3)	52	20.7 (0.815)
December, 2013	26.4 (79.5)	14.1 (57.4)	50	12.8 (0.504)

Source: "Weatherbase: Historical Weather for Dhaka, Bangladesh". Weatherbase.com
"Bangladesh - Dacca" (in Spanish). Centro de Investigaciones Fitosociológicas.
"Average Conditions - Bangladesh - Dhaka". BBC

Appendix - III: Some Commonly Used Abbreviations and Symbols

Abbreviations	Full word
%	Percent
@	At the rate
^{0}C	Degree Celsius
^{0}F	Degree Fahrenheit
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BSMRAU	Bangladesh Sheikh Mujibur Rahman Agricultural University
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of coefficient of variation
DMRT	Duncan's Multiple Range Test
et al.	and others
etc	et cetera
FAO	Food and Agricultural Organization
g	gram
hr.	Hours
j.	Journal
kg	Kilogram
Kg/ha	Kilograms per hectare
LAD	Leaf area diseased
m	Meter
mm	Millimetre
MSE	Mean square of the error

No.	Number
ppm	Parts per million
RCBD	Randomized complete block design
Rep.	Replication
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sc.	Science
SE	Standard Error
Temp	Temperature
Univ.	University
var.	Variety
Wt.	Weight