EFFECTS OF FERTILIZER, MANURE AND WATER MANAGEMENT ON THE NUTRIENT AVAILABILITY, LEACHING, SOIL FERTILITY AND PRODUCTIVITY UNDER RICE- RICE CROPPING PATTERN

MOSAMMAT SELINA AKTAR SAMPA

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

JUNE, 2017

EFFECTS OF FERTILIZER, MANURE AND WATER MANAGEMENT ON THE NUTRIENT AVAILABILITY, LEACHING, SOIL FERTILITY AND PRODUCTIVITY UNDER RICE- RICE CROPPING PATTERN

BY

MOSAMMAT SELINA AKTAR SAMPA
REGISTRATION NO.: 13-05794

A Thesis
submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

DOCTOR OF PHILOSOPHY
IN
SOIL SCIENCE

SEMESTER: JANUARY-JUNE, 2017

APPROVED BY:

Prof. Dr. Md. Asaduzzaman Khan
Chairman
Advisory Committee

Prof. Dr. M. Rafiqul Islam	Prof. Dr. Alok Kumar Paul	Prof. Dr. Parimal Kanti Biswas
Member	Member	Member
Advisory Committee	Advisory Committee	Advisory Committee

Dr. Md. Asaduzzaman Khan
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Mob.: +8801552498705
Email: makhan@yahoo.com

This is to certify that the thesis entitled, "*EFFECTS OF FERTILIZER, MANURE AND WATER MANAGEMENT ON THE NUTRIENT AVAILABILITY, LEACHING, SOIL FERTILITY AND PRODUCTIVITY UNDER RICE- RICE CROPPING PATTERN*" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of *DOCTOR OF PHILOSOPHY IN SOIL SCIENCE,* embodies the result of a piece of bonafide research work carried out by *MOSAMMAT SELINA AKTAR SAMPA*, Registration No. **13-05794** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Asaduzzaman Khan)
Chairman
Advisory Committee
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

DEDICATED

TO

MY BELOVED FAMILY

ACKNOWLEDGEMENTS

All praises are due to Almighty Allah, the Great, Gracious and Merciful, whose blessings enabled the author to complete this research work successfully.

The author likes to express her deepest sense of gratitude to ***Prof. Dr. Md. Asaduzzaman Khan,*** *Chairman, Advisory Committee,Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement and invaluable suggestions and constructive criticism throughout the study period in conducting and successfully completing the research work and in the preparation of the manuscript.*

The author also expresses her gratefulness to ***Prof.Dr. Alok Kumar Paul,****Member, Advisory Committee, Department of Soil Science, a foSher-e-Bangla Agricultural University, Dhakr his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.*

The author is ever grateful, immensely indebted to ***Prof. Dr. M. Rafiqul Islam****, Member, Advisory Committee, Department of Soil Science, Bangladesh Agricultural University, Mymensingh for his sympathy, kind co-operation, inspiration, scholastic supervision and suggestions, constructive criticism and valuable advice for the completion of this research work.*

The author is highly indebted and expressing her heartfelt appreciation and gratification to ***Prof. Dr. Parimal Kanti Biswas****, Member, Advisory Committee, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, guidance and helpful suggestions.*

The author would like to express her deepest sense of gratitude, sincere appreciation; profound regards to her respectable all teachers, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their encouragement and kind co-operation throughout the course of the study.

The author expresses her sincere respect to the Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the respected teachers of the Department of Soil Science, SAU, for their valuable suggestions, instuctions, cordial help and encouragement during the period of the study.

The author expresses her sincere appreciation to her family members, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.The author expresses heartfelt thanks toher husbandfor his inspiration, valuable suggestions, instuctions, cordial help and encouragement during the period of the study

Dhaka Bangladesh *The Author*

June, 2017

ABSTRACT

Three experiments were conducted at the net house and research field of Sher-e-Bangla Agricultural University during January 2013 to June 2014 to study the effects of fertilizer, manure and irrigation on the nutrient availability, leaching, soil fertility and productivity under rice-rice cropping pattern. A net house experiment with 30 (2 levels of irrigation x 5 fertilizer treatments x 3 replications) undisturbed soil columns (40 cm length and 30 cm diameter) was set up at a net-house of SAU, with rice growing in boro and T. aman seasons during January 2013-December 2013. Soil cores were placed on the plastic containers and leachate collection systems were developed. BRRI dhan29 and BRRI dhan33 were grown on the cores with two levels of irrigation (I_1: continuous flooding I_2: saturated condition) and fertilizer treatments (T_0: Control T_1: RDCF, T_2: 50% NPKS + 5tha^{-1} cowdung, T_3: 50% NPKS + 5 tha^{-1} compost, T_4: 50% NPKS+ 3.5 tha^{-1} poultry manure. The leachate samples were analyzed for nutrient during the growing seasons. The leachate nutrient concentration varied with irrigation, fertilizer and time of sample collection. Higher levels of leachate N, K and S concentrations were found in the T_4 treatment. Phosphorus leaching decreased with increasing days from transplantation but N and S leaching were in similar trend during the rice growing period. Application of organic plus inorganic fertilizer increased the level of organic matter, P and K availability of post experiment soils. Application of poultry manure increased more the soil pH, available P and level of organic matter in post-experiment soils. The continuous flooded irrigation in combination with different fertilizer treatments increased the level of K in post-harvest soil. A field experiment involving 2 levels of irrigation and 8 fertilizer treatments (2x8x3= 48 plots) were applied in the boro rice field soil and without rice planted soil (PVC pipe installed fallow area) during January 2014-June 2014**.** The experiment was laid out in split plot design with irrigation (I_1: traditional irrigation i.e. continuous flooding and I_2: saturated condition) to the main plots and fertilizers to the sub plots. The fertilizer treatments were T_0 =Control, T_1 =$N_{120}P_{25}K_{60}S_{20}Zn_2$ (RDCF), T_2 =50% NPKS + 5 tha^{-1}cowdung, T_3=70% NPKS + 3 tha^{-1}cowdung, T_4 =50% NPKS + 5 tha^{-1} compost, T_5 =70% NPKS + 3 tha^{-1} compost, T_6 =50% NPKS + 3.5 tha^{-1} poultry manure, T_7 =70% NPKS + 2.1 ton poultry manure ha^{-1}. Boro- T. aman rice experiments were conducted previously in the same plots with the application of same treatments from 2012. The effect of residual and renewal application of fertilizer and manure influenced the pore-water nutrient availability, yield and the fertility of post experiment soils. The higher grain yields were obtained in inorganic plus organic treatments. The highest grain yield was obtained from I_2T_7, I_2T_5 and I_1T_5 treatment combinations. The higher concentrations of N, P and K were found in the pore-water of T_6 and T_7 treatments where higher yields were also obtained. Pore-water P concentrations decreased with increasing days after transplantation. At flowering stage, the highest pore-water P was found in I_1T_4 treatment combination. Higher concentrations of pore-water K were found into the core (fallow area) than rice root zone area (outside) during the cropping season. Higher N, P and K concentrations were found in the post-harvest soils (root zone area and fallow area) where manures were applied. The higher levels of organic matter were found in the post-harvest soils of T_2 treatment of rice root zone area (1.60%) and the soils of fallow area (1.59%). The application of poultry manure increased the pH of the soil. Another field experiment was conducted at SAU Farm with rice growing in boro and T. aman seasons during July 2013 to June 2014. The three levels of irrigation (I_1: continuous flooding, I_2: saturated condition and I_3: Alternate wetting and drying) and eight fertilizer treatments (similar to expt. 2) were applied in this experiment. The highest T. aman rice yield was found from I_2T_2 and the highest grain yield of boro rice (7.94 t/ha) was recorded with the treatment combination I_1T_7. The pH of 6.9 was obtained in the soil where inorganic fertilizer and poultry manure were applied.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is one of the major crops of the world. It is a semi aquatic annual grass plant and is the most important cereal crop in the developing world. 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. Global production dropped sharply at the beginning of the 21^{st} Century, from 410 million tons in 2000 to 378 million tons in 2003 bec*aus*e of severe droughts in parts of Asia, but has recovered by growing 50 million tons between 2005 and 2011 (Rejesus *et al*., 2012). A study showed that most Asian countries won't be able to feed their projected population without irreversibly degrading their land resources, even with high levels of management inputs (Beinroth *et al*., 2001).

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 and uptake of nutrients in soil are 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 and S 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.

Rice is intensively cultivated in Bangladesh which covers about 80% of the total cultivable land. But the population density is higher that can't provide them with their whole requirements of food. The main thing is that in Bangladesh the yield of rice is low compare to the other rice growing countries like Japan, South Korea where the average yield is 6.22

and 7.00 ton per hectare chronologically (Islam *et al*., 2013) and the demand is increasing day by day in Bangladesh.

Researchers have been trying to improve the production systems with the help of combination of organic and inorganic sources of nutrients. The improvement of soil physico-chemical properties by using both chemical and organic fertilizers supplies essential plant nutrient for higher yield. The application of different levels of irrigation affects the yield, nutrient accumulation and quality of boro rice. More nutrients are leached out from soil when higher levels of irrigation water are added during boro rice growing period. Yang *et al.* (2004) reported that application of chemical fertilizers with farmyard manure or wheat or rice straw in alternate wetting and drying condition increased N, P, & K uptake by rice plants. Organic manure can supply a good amount of plant nutrients, contributing 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 organic and inorganic sources of nutrients helps in improveing 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 determine 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.

In 1996, 453 78 420 49 million tons of NPKS respectively were removed by grain and straw, while in the same year 572 251 234 43 million tons of NPKS, respectively, (BBS 2014) were added in the form of inorganic fertilizers. The gap between nutrient removal and supply is likely to be widen further due to a number of reasons like pressure on land, increased demand for cereal food grain. The nutrient requirement in near future could not be met by natural sources alone. Mineral fertilizer inputs are the crucial factors to the over all nutrient balance in intensive cropping systems. Organic matter content of most of the soils of Bangladesh is very low (0.8 to 1.8%) as compared to desired (2.5% and above) levels. Fertilizers have been responsible for nearly 50% yield increases registered in recent years. But the current fertilizer use in Bangladesh is highly imbalanced because of its limited availability and unfavourable fertilizer, produce price ratio and its use is rarely decided by local recommendation. Organic materials in combination with chemical fertilizers showed excellent response to rice cultivation. Imbalanced use of inorganic fertilizers and soil nutrient mining has resulted in declining soil fertility and therefore, stagnating or decreasing of crops yields. Balanced fertilization carry different meanings considering the nutrient input-output relationship in soil plant system, ratio of fertilizer products and balanced in cost and return of fertilization.

Fertilizer N spatial distribution and plant N absorption are affected by N forms and soil types. Previous research has shown that N translocation of ammonium sulphate mainly occurred in the 0–5 cm soil layer when the fertilizer rate was three times the conventional rate (Sun *et al*., 2012 **;** Zhang *et al*., 2011). The mobility of fertilizer N is faster in sandy soils than in loamy soils. As a result, the losses caused by leaching and runoff from sandy soils can be considerable. N leaching in sandy soils was about 73 kg N ha^{-1} $year^{-1}$ on grassland, which was significantly higher than for clay soils (15 kg N ha^{-1} $year^{-1}$). Therefore, careful fertilizer management, where low doses are applied as a number of split applications over the growing season, is recommended for sandy soil. RZF has been reported to significantly decrease NH_3 volatilization, reduce fertilizer N surface runoff, prevent nitrous oxide and nitric oxide emissions from nitrification and denitrification (Rochette *et al*. 2013; Gaihre 2015), and increase grain yield and nutrient use efficiency. The effects of a one—time RZF application on rice have been reported in South and South (Miah *et al*., 2016). However, little systematic research has been carried out on the movement of N, P, K and S in paddy soil.

N translocation and transformation mainly occurs in the 0–5 cm soil layer (Sun *et al*. 2012**;** Zhang *et al*. 2011) and NH_4^+, which is hydrolyzed from urea, tends to move downwards in water. Therefore, we applied fertilizer N at 5 cm horizontal distance and 10 cm depth in the RZF experimental sites (Rochette *et al.*, 2013, Gaihre, 2015). Nitrogen (N) is ubiquitous in the environment. It is also one of the most important nutrients and is central to the production of all crop plants. However, N also forms some of the most mobile compounds in the soil-plant-atmosphere system. There is mounting concern about agriculture's role in N delivery into the environment, as nitrogen represents the mineral fertilizer most applied to agricultural land. This is because available soil-N supplies are generally inadequate for optimum crop production. The fate and transport of N from the various sources used to supply the N-requirements of crops in the context of the N cycle. Use of N budgets, or a mass balance approach, is needed to understand the options for improving management of N in farming and livestock systems and for mitigating the environmental impacts of N. Fertilizing crops for crop-N uptake that will be near the point of maximum yield is in general an economically and environmentally acceptable practice (BARI, 2000). The management objective is to lower the rate and duration of the loss processes themselves. Practices and concepts are considered that lessen the opportunity for loss processes to occur and that help to decrease the amount of N that may be lost to the environment. In some cases improved efficiency is achieved by using less nutrients; in other cases it can be achieved by increasing the yield while using the same amount of N-input. In either case, the goal is to decrease the total residual mass of N in the soil. Another approach is to keep the residual N within the soil-crop system by curtailing the transport processes (leaching, runoff, erosion, and gaseous losses) that carry pollutants out of the system.

New insights into how phosphorus leaches into groundwater could help reduce its potential impact on water and the environment, pollutants as the phosphorus poses an environmental threat when it moves from soils to open water bodies, including lakes, streams and rivers. When too much phosphorus is applied to soils, the ground cannot hold all of the chemical. As a result, phosphorus leaches out and migrates to water bodies, lowering water quality and leading to algal blooms. It is important to know the P leaching through the soil column and the amount of residual P retained in the paddy soil with the application of different level of irrigation, fertilizer and manure.

Potassium (K) is an essential nutrient for plant growth and is classified as a macronutrient due to large quantities of K being taken up by plants during their life can supply some K for crop production, but when the supply from the soil is not adequate, K must be supplied in a fertilizer program. Potassium that is dissolved in soil water (water soluble) plus that held on the exchange sites on clay particles (exchangeable K) is considered readily available for plant growth. The exchange sites are found on the surface of clay particles. This is the form of K measured by the routine soil testing procedure. Plants readily absorb the K dissolved in the soil water. As soon as the K concentration in soil water drops, additional K is released into the soil solution from the K attached to the clay minerals. The K attached to the exchange sites on the clay minerals is more readily available for plant growth than the K trapped between the layers of the clay minerals. It was noticed that when the arrows go in both directions, one form of K is converted to another. The rate of conversion is affected by such factors as root uptake, fertilizer K applied, soil moisture, and soil temperature. Potassium uptake by plants is affected by several factors. Higher soil moisture usually means greater availability of K. Increasing soil moisture increases movement of K to plant roots and enhances availability. Research has generally shown more responses to K fertilization in dry years. Air is necessary for root respiration and K uptake. Root activity and subsequent K uptake decrease as soil moisture content increases to saturation.

In the soil, sulfur occurs in organic and inorganic forms and is cycled within and between those forms via mobilization, immobilization, mineralization, oxidation, and reduction processes. Organic sulfur compounds are largely immobile. Inorganic sulfur compounds are more mobile, and sulfate is the most mobile. However, adsorption onto soil limits or delays sulfate ion transport. Nonspecifically adsorbed sulfate ions are held only by electrostatic charges in the double diffuse layer, so they are not held as tightly as specifically adsorbed ions that are bonded to metal oxides in the Helmholtz layer. Sulfate adsorption and desorption are controlled predominantly by pH, sulfate concentrations, concentrations and types of other cations and anions in solution, and the character of the colloidal surfaces. Watershed hydrology and subsurface flow paths play important roles in determining the fate of sulfate in soils. Sulfate transport and retention in soil focus on soil materials, macropore and micropore flow and overall soil moisture conditions. Retention also is affected by deposition levels. The main transformations within the S cycle occur among immobilized, mobilized, and mineralized S compounds. Immobilization, or the assimilation of S into microbial cells, depends completely on microbial metabolism. Both aerobic and anaerobic microorganisms take part in organic S formation, though only 1 to 3 percent of microbial biomass is composed of S. The short life cycles of microorganisms, however, result in rapid turnover and S recycling. Microbial biomass has been described as the most active and readily available form of soil organic S, and much of the mineralized S seen in short-term incubation experiments may originate from microbial biomass. Some adsorbed SO_4^{-2} may be desorbed and incorporated into low molecular weight organic compounds, which later can be polymerized to larger insoluble organic compounds.

Increasing water scarcity necessitates the development of irrigated rice systems that require less water than traditional flooded rice. In irrigated aerobic rice systems, rice grows in non flooded and non-saturated soil under supplemental irrigation. The development of such systems should start with the identification of promising varieties and the quantification of yield potential, water use, field water outflows, and water productivity. The impact of saturated soil conditions on nutrient availability and losses differs with each of the macronutrients. Under saturated soil conditions, losses of soil nitrogen can be substantial. Nitrate nitrogen can be lost by leaching down and out of the reach of crops. While leaching occurs rapidly on coarse textured sandy soils, it is a slower process on loam and clay soils due to slower water movement. In addition, soil microorganisms are not very effective at decomposing crop residues and organic matter when the soil is saturated, slowing the release of nitrogen from this source.

The mobility of sulfate makes it subject to leaching, similar to nitrate. However, unlike nitrate, losses of sulfate by volatilization from the soil are negligible. As a result, in the absence of leaching, soil sulfur is not affected to any great extent under conditions of excess water. Being a nutrient that comes mainly from the soil organic matter, sulfur is impacted by any physical factor that restricts microbial assisted release. The rice yields, soil fertility as well as plant uptake as governed by the availability and leaching of nutrients. The N, P, K and S availability and leaching in soil are influenced by irrigation and fertilizer management. The nutrient availability, leaching in relation to soil productivity and fertility are still imperfectly understood. Detailed study on the nutrient availability in pore water and leaching in relation to improving soil fertility and productivity are still lacking. It is important to carry out studies to understand the nutrient leaching, availability, improvement of fertility and productivity in paddy soil.

This detailed study was taken under with the following objectives:

i. To determine the loss of nutrient through leaching with different fertilizer, manure and water management systems.
ii. To evaluate the effect of irrigation, fertilizer plus manure on the growth and yield of rice.
iii. To evaluate the effect of fertility of post-harvest soils with different treatment combination of fertilizer and irrigation.
iv. To determine judicial use of fertilizer plus manure with proper water management for improving soil fertility, nutrient availability and productivity.
v. To know the effect of fertilizer, manure and water management on the change of physicochemical properties of soil.

Experiment wise specific objectives

Experiments	**Objectives**
Experiment 1: Effects of fertilizer, manure and irrigation on nutrient contents in leachate and yield of rice	i) To determine the loss of nutrient through leaching with different fertilizer, manure and water management systems. ii) To evaluate the effect of fertility (NPKS) of post experiment soils with different treatment combination of fertilizer and irrigation. iii) To evaluate the effect of irrigation, fertilizer plus manure on the growth and yield of boro and T. aman rice.
Experiment 2: Integrated use of organic and inorganic fertilizer on nutrient in pore water, yield contributing character and yield of rice under traditional and saturated irrigation condition	i) To evaluate the effect of irrigation, integrated use of organic and inorganic fertilizer on the growth and yield of boro rice. ii) To evaluate the effect of irrigation, integrated use of organic and inorganic fertilizer on the nutrient availability of root zone and outside the root zone of boro rice at different growth stage. iii) To evaluate the effect of irrigation, integrated use of organic and inorganic fertilizer on the post experiment soil fertility status (NPKS) of boro rice field.
Experiment 3: Integrated use of fertilizer and manure on rice yield, soil fertility and nutrient availability under different irrigation management system in rice – rice cropping pattern	i) To evaluate the effect of irrigation, integrated use of organic and inorganic fertilizer on the growth and yield of T. aman rice. ii) To evaluate the effect of irrigation, integrated use of organic and inorganic fertilizer on the growth and yield of boro rice. iii) To evaluate the effect of the integrated management of irrigation, organic and inorganic fertilizer in both boro rice- fallow-T. aman rice cropping system on the post experiment soil fertility status (NPKS).

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Soil organic manure and inorganic fertilizer are the essential factor for sustainable soil fertility and crop productivity as organic matteris 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 fertilizers 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. On the other hand Irrigation also an important factor for the sustainable nutrient availability, soil fertility and crop productivity. Some literature related to the "EFFECTS OF FERTILIZER, MANURE AND WATER MANAGEMENT ON NUTRIENT AVAILABILITY, LEACHING, SOIL FERTILITY AND PRODUCTIVITY UNDER RICE-RICE CROPPING PATTERN" are reviewed below-

In agriculture, leaching refers to the loss of water-soluble plant nutrients from the soil, due to rain and irrigation. Irrigation, crop planting, type and application rates of fertilizers, and other factors are taken into account to avoid excessive nutrient loss. Leaching is a process of extracting a substance from a solid material that is dissolved in a liquid. This process is commonly referred to as extraction, particularly in the chemical industry. The whole issues of influence of fertilizer and manure, irrigation and water management on plant nutrient availability, nutrient leaching, soil fertility and productivity under Rice- Rice cropping system in Bangladesh are technically reviewed in this chapter, The total review is performed under several main headings and sub-heading as per three experiments formulated for the research were done and accordingly mentioned here sequentially as per objectives of each of the experiment.

2.1 Effect of Irrigation on Nutrient Leaching and Availability

2.2 Effect of Fertilizers and Manure on Nutrient Leaching and Availability

2.3Effect of Irrigation on Rice Yield

2.4 Effects of Integrated Nutrient Management on the Yield of rice and improvement of soil fertility.

2.1 Effect of Irrigation on Nutrient Leaching and Availability

Li *et al.* (2013) conducted an experiment on using a simple soil column method to evaluate soil phosphorus leaching risk In this study, a simple soil column method was developed using two calcareous Fluvisols, silt loam and loam. The soil column was 20 cm in length and 5 cm in diameter and distilled water was continuously supplied from the top. The volume and dissolve dreactive P (DRP) concentrations of leachate were measured. Results showed that DRP concentrations in leachate increased slowly for the low soil Olsen-P levels but rapidly for the high Olsen-P levels. The P leaching intensity of soils increased by 3- to 540-fold if the soil Olsen-P contents accumulated from 6.6 to155.5mgP kg^{-1}. The outcomes derived from this study regarding the determination of P leaching threshold and intensity by the soil column method also need a further verification on more soils with a wide range of physical and chemical properties.

Islam *et al.* (2009) conducted a net house experiment in the Department of SoilScience, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh to find out the leaching loss of N, P, and K in the Old Brahmaputra Floodplain Soil under continuous standing water (CSW) condition. The soil was sandy loam in texture having pH 6.6, total N 0.08%, available P 7.00 $mgkg^{-1}$, exchangeable K 0.07 me/100g soil, and available S 7.5 $mgkg^{-1}$. There were six treatments, such as T_0 (control), T_1 (N_{120} P_{25} K_{60} S_{20} recommended dose), T_2(N_{180} P_{37} K_{90} S_{30} $kgha^{-1}$ i.e., 150% of the recommended dose), T_3 (75% N of T_1 from chemical fertilizer and 25% N from cowdung 2.5 t ha^{-1} and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung), T_4 (as T_1 but N109 kg ha^{-1} from USG) and T_5 (as T_1 but N applied as foliar spray). The nutrients P, K, and S were applied as basal dose in the pots while urea was applied in three equal splits except T_4 and T_5. One USG per pot was placed after 7 days of transplanting in T_4. In T_5, urea was applied as foliar spray at 10 days interval. Leachates from individual pots were collected at 15 days intervals to determine the amount of loss of NPK. Results showed that leaching loss of NPK in the sandy loam soil under CSW condition varied widely due to different treatments over time. The total leaching loss of N, P and K during the growing season varied from 22.23 to 91.21, 0.063 to 1.95, and35.22 to 42.01 kg ha^{-1}, respectively. Application of chemical fertilizer at high errates resulted in greater loss of nutrients. Integrated approach of fertilizer management could minimize such losses to a great extent. Application of N in the form of USG reduced the N loss significantly.

Peng *et al.* (2008) carried out an experiment on nitrogen and phosphorus leaching losses from paddy fields with different water and nitrogen managements to assess nitrogen and phosphorus leaching losses under real conditions in different water and N managements. Two water and three N treatments are conducted in the Taihu Lake region of China. Results show that the total N leaching losses during the rice season under flooding irrigation (FI) are 12.4, 9.31, and 7.17 kg ha^{-1} for farmers' fertilization practices (FFP), site-specific N management (SSNM), and controlled-release nitrogen fertilizer management (CRN), respectively. Under controlled irrigation(CI), the respective losses were 7.40, 5.86, and3.79 kg ha^{-1} for the same management methods. The total P leaching losses during the rice season under FI were0.939, 0.927, and 0.353 kg ha^{-1} for FFP, SSNM, and CRN, respectively. Under CI, the losses were 0.424, 0.433 and 0.279 kg ha-1, respectively, for the same management methods. Ammonium and nitrate N accounted for42.2–65.5% and 11.8–14.7% of the total nitrogen leaching losses under different water and N management methods, respectively. Due to significant decrease of volumes of percolation water and nitrogen and phosphorus concentrations in percolation water, N and P leaching losses were reduced in the CI treatment compared to the FI treatment under the same N management. The reduction of N in put and application of controlled-release nitrogen fertilizer can reduce N and P leaching losses from paddy fields.

Tan *et al.* (2007) conducted an experiment on the the effects of AWD on percolation, water productivity, nitrogen leaching losses and nitrogen productivity through in situ experiments. Results show that AWD reduced irrigation water without a significant impact on grain yields and increased the mean water productivity by 16.9 % compared with continuously flood irrigation (CFI). The percolation was reduced by 15.3 % in 2007 and 8.3 %in 2008 compared to CFI. However, the cumulative percolation of the first 5 days after irrigation in AWD plots is significantly larger than that in CFI plots. The NH_4–N and TN leaching losses of AWD and CFI had no significant variations while the NO_3–N leaching losses were increased caused by AWD. The total NH_4–N, NO_3–N and TN losses of AWD in the first 3 days after irrigation.The results indicate that the bypass or preferential flow and strengthened nitrification–denitrification nitrogen transformation processes because of alternate wetting and drying potentially decrease the water saving effectiveness and increase the NO_3–N loading to the groundwater.

Matin *et al.* (2013) conducted an experiment to investigate the influence of water logging on availability of nutrients in paddy soils. The five soils were incubated under a waterlogged condition at 30^o C for 12 weeks. The EC, Eh, pH, NH_4, K, Na, Ca, Mg, Cl, P, Fe, and Mn of soil solutions were monitored over the waterlogged period. The Eh values generally dropped to the lowest point within 14 days of water logging, then increased, and reached equilibrium after 8 weeks of water logging. The soil pH decreased in the first 2–4 weeks of water logging. The EC values increased partly due to dissolution of soluble salts in the first 2 weeks. The concentrations of soluble NH_4 were significantly increased with water logging, reached maximum values at week 4–6, and then declined to the initial level. Water logging increased the concentration of soluble K, Ca, Mg, Fe, and Mn ions, the magnitudes of changes were greatly affected by soil properties. Increases in soluble Na, K, Ca, and Mg were attributed to the increase in solubility of insoluble salts and increase in competition for the exchange sites. Increases in soluble Fe and Mn induced by water logging were attributed to the dissolution of Fe and Mn oxides under reduced conditions.

2.2 Effect of Fertilizer and Manure on Nutrient Leaching and Availability

Islam *et al.* (2011) conducted in a net house of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during July–November to study the effect of fertilizer and manure on the growth and yield of T. aman rice and leaching loss of nutrients through undisturbed soil columns. The experiment consists of 2 factors i.e. soils and fertilizer plus manure. Two soils (S_1= SAU Soil and S_2= Sonargaon Soil) with 4 levels of fertilization, as F_0: Control, F_1: 100% $N_{120}P_{20}K_{45}S_{20}$ (FRG 2012), F_2: 50% NPKS + 5 t/ha cowdung, F_3: 50% NPKS + 2.1 t/ha poultry manure were used in the experiment. T. Aman (BR11) rice was grown in the soil cores. The leachate N, P, K and S concentration varied with different soil, fertilizer and time. The higher N and S concentrations were found in the leachate of SAU soil and higher leachate K concentrations were obtained in Sonargaon soil. The higher amounts of N leaching were observed during 45–55 DAT and higher leachate N concentrations were found in F_1 treatment. Higher leachate K concentrations were found in 100% chemical fertilizer treatment and higher leachate K concentrations were found at 35DAT in all fertilizer treatments. The leachate P concentration increased at 35 DAT and then decreased. The yield contributing characters and yields were significantly affected by fertilizer and manure application. The highest effective tillerscore^{-1} (17.0), plant height (105.6 cm), panicle length (23.70 cm), grain yield (0.046 kgcore^{-1}) and straw yield (0.053 kg core^{-1}) of T. Aman rice were found from F1 (RDCF) treatment. The highest 1000-grain wt. (23.70 g) was obtained from F_2 and filled grain/panicle (121.8) from T_3 treatment and the lowest in F_0 treatment. The highest grain yield was found by the application of recommended dose of chemical fertilizer which was statistically similar to F_3 (50% NPKS + 2.1 ton poultry manure) treatment. The combined effects of soil and fertilizer were not significant but the highest grain (0.049 kg core^{-1}) and straw yields (0.056 kg core^{-1}) were recorded from S_2F_1 (Sonargaon Soil + 100% NPKS) treatment combination.

Wang *et al*. (2007) carried out an experiment on nitrogen and phosphorus leaching losses from intensively managed paddy fields with straw retention. With straw retention, the percolation rate had a significant ($p < 0.05$) negative exponential relationship with the day after rice transplanting, accounting for an average 2.57 mm d^{-1}. NH_4^+-N and NO_3–N concentration in percolation increased with increasing of N fertilizer application rate. Compared to the control (without straw or fertilizer), the wheat straw incorporation without N fertilizer decreased the concentration of NH_4+-N and NO_3–N but promoted TP concentration. Cumulative inorganic N (NH_4^+-N + NO_3–N) and P losses were about 14.4 and 0.53 kg ha^{-1},accounting for 5.6% and 3.5% of N and P fertilizer applied. NH_4^+-N leaching losses accounted for 62–97% of the total leaching of inorganic N. Nitrogen leaching losses occurred mainly at the basal fertilizer application stage, accounting for 76.8% of total N leaching. Straw retention reduced the N leaching losses because the straw can enhance microbial N immobilization due to its high C:N ratio.

Entry*et al*. (2007) carried out an experiment on matrix based fertilizers (MBFs) reduced nitrogen and phosphorus leaching in three soils to compared the efficacy of matrix based fertilizers formulated to reduce NO_3^-, $NH_4^{+,}$ and total phosphorus (TP) leaching, with Osmocoate®14-14-14, a conventional commercial slow release fertilizer (SRF) and an unamended control in three different soil textures in a greenhouse column study. The MBFs covered a range of inorganic N and P in compounds that are relatively loosely bound (MBF 1) to more moderately bound (MBF 2) and more tightly bound compounds (MBF 3) mixed with $Al(SO_4)_3H_2O$ and/or $Fe_2(SO_4)_3$ and with high ionic exchange compounds starch, chitosan and lignin. When N and P are released, the chemicals containing these nutrients in the MBF bind N and P to a Al $(SO_4)_3H_2O$ and/or Fe_2 $(SO_4)_3$ starch–chitosan–lignin matrix. One milligram (8000 spores) of *Glomusintradices* was added to all formulations to enhance nutrient uptake. In all three soil textures the SRF leachate contained a higher amount of NH_4^+,$NO_3^-$and TP than leachate from all other fertilizers. In all three soils there were no consistent differences in the amount of $NH4^+$,$NO3^-$and TP in the MBF leachates compared to the control leachate. Plants growing in soils receiving SRF had greater shoot, root and total biomass than all MBFs regardless of $Al(SO_4)_3H_2O$ or $Fe_2(SO_4)_3$ additions. Arbuscularmycorrhizal infection in plant roots did not consistently differ among plants growing in soil receiving SRF, MBFs and control treatments. Although the MBFs resulted in less plant growth in this experiment they may be applied to soils growing plants in areas that are at high risk for nutrient leaching to surface waters.

Kleinman*et al*. (2005) carried out an experiment investigated vertical leaching of P through two soils. Eight 30 and 50 cm deep, intact soil columns (30 cm diameter) were collected. Columns were irrigated periodically (2.4 cm day^{-1}) before and after surface application of poultry manure (85 kg total P ha^{-1}), continuing for 11 weeks after the application. A dye tracer (FD and C blue No. 1) was used to identify the presence of active macropores at the bottom of each column, and to compare properties of undyed soil matrix material with dyed soil bordering active macropores. Before manure application, concentrations of total P (TP) in leachate did not exceed 0.57 mg L^{-1}, with dissolved reactive P (DRP) a minor fraction of leachate TP (averaging 7%). Manure application resulted in significant increases in leachate P concentrations, with DRP averaging 72%of leachate TP. No significant differences in leachate DRP and TP concentrations were observed between 30 and 50 cm deep columns or between soils, either before or after manure was applied, reflecting considerable variability in leachate P trends. In many columns, P concentrations in leachate peaked soon after manure application, with maximum DRP concentrations ranging from 1.1 to 11.2 mg L^{-1}. In other columns, concentrations increased slowly over time, but maximum DRP concentrations were only 0.19 to 0.55 mg L^{-1}. Different temporal trends in leachate P concentrations were unrelated to trends in flow. Increased P sorption saturation of soil bordering macropores in subsurface horizons, due to elevated Mehlich-3 P and depleted Mehlich-3 Al, points to the importance of macropores as preferential flow pathways for P.

Zhang *et al.* (2000) conducted an experiment to assess phosphorus losses by runoff and vertical leaching, which are considered the two main pathways of P movement from paddy soil into its surrounding water course. Commercial NPK compound fertilizer and single superphosphate fertilizer were applied to furnish 0, 30, 150, and 300 kg applied P ha m^{-2}.

Results revealed that the average concentration range for total P (TP) in runoff was 1.857–7.883, 1.038–5.209, 0.783–1.255 and 0.572–0.691 mg P l^{-1} respectively for P_{300}, P_{150}, P_{30} and P_0 in Anzhen, while it was 2.431–2.449, 1.578–1.890, 1.050–1.315 and 0.749–0.941 mg P l^{-1} respectively in Changshu. In all treatments, particulate P (PP) represented a major portion of the TP lost in runoff, it was 80% in Anzhen, and it was even more (>90%) in Changshu. Phosphate fertilizer treatments significantly affected P concentrations and P loads in the runoff. The mean concentration and average seasonal TP load from the P_{150} plots were 1.809 mg P l^{-1} and 395 g P ha m^{-2} $season^{-1}$ respectively, and lower than that from the P_{300} plots (2.957 mg P l^{-1} and 652 g P ha m^{-2} $season^{-1}$). These were obviously higher than from the P_{30} (0.761 mg P l^{-1} and 221 g P ha m^{-2} $season^{-1}$) and P_0 (0.484 mg P l^{-1} and 146 g P ha m^{-2} $season^{-1}$) respectively. There was no significant difference found between the P_{30} and the P_0 in both sites. Under usual P application rate, there were total 31.7 and 20.6 tones P removed by runoff from permeable (Anzhen site) and waterlogged (Changshu site) paddy soils in the southern Jiangsu region (major part of the TLR) in the rice season of the year 2000The average concentration of molybdate reactive phosphorus (MRP) in the vertical leachate from the four different P treatments ranged from 0.058 to 0.304 mg P l^{-1} in Anzhen and from 0.048 to 0.394 mg P l^{-1} in Changshu. P application rate significantly affected the MRP concentration at each depth in both sites, except for the 90 cm in Anzhen. The average MRP loads during the rice season moved by vertical leaching from the four treatments ranged from 163 to 855 g P ha m^{-2} $season^{-1}$ in Anzhen and 208–1825 g P ha m^{-2} $season^{-1}$ in Changshu.

Morshedizadand Leinweber (2015) carried out an experiment to study the effect of BC, surface-modified BC (BCplus) and sulfur-enriched activated char (ACS) application at different particle sizes on P- and Cd-mobilization under non-equilibrium conditions in a combined incubation-leaching experiment. Two soils each with the treatments (i) BC, (ii) BC plus, (iii) BC þ ACS, (iv) control (0mgP kg^{-1} soil), and (v) ACS were leached five times during70 days incubation. Over the complete incubation P-contents in leachates were significantly increased by BC and BC plus of 0.5–1mm size. The lowest leachate Cd-concentrations were found in soils amended with the smallest BC particles. Addition of BC plus and ACS significantly increased Cd leaching and the highest amounts of Cd were leached at the smallest particle size. In conclusion, the 0.5–1 mm size class of BCs performed best and should be introduced in practical agriculture using standard machinery.

Lee *et al*. (2014) conducted an experiment to estimate the contribution of applied N fertilizer to N turnover in rice paddy soil with different N fertilization practices that were manipulated by the quantity of treated swine slurry and chemical N fertilizer (i.e., HTSS + LAS, a high amount of TSS with a low amount of ammonium sulfate; LTSS + HAS, a low amount of TSS with a high amount of ammonium sulfate; AS, ammonium sulfate with phosphorus and potassium; C, the control) and (2) to compare the rice response to applied N derived from each N fertilization practice. Rice biomass yield, 15 N recovery in both rice grain and stems, soil total N (TN), soil inorganic N, and soil 15 N recovery were analyzed. Similar amounts of 15 N uptake by rice in the TSS+AS plots were obtained, indicating that the effects of the different quantities of TSS on chemical fertilizer N recovery in rice during the experimental period were not significant. The soil 15 N recoveries of HTSS + LAS, LTSS + HAS, and AS in each soil layer were not significantly different. For the HTSS + LAS, LTSS + HAS and AS applications, total 15 N recoveries were 42 , 43 and 54%, respectively. Because the effects of reducing the use of chemical N fertilizer were attributed to enhancing soil quality and cost-effectiveness, HTSS + LAS could be an appropriate N fertilization practice for improving the long-term sustainability of paddy soil-plant systems. However, N losses, especially through the coupled nitrification-denitrification process, can diminish the benefits that HTSS+LAS offers.

2.3 Effect of Irrigation on Rice Yield

Saleque *et al.* (2008) stated from their findings on Long-term effects of inorganic and organic fertilizer sources on yield and nutrient accumulation of lowland rice that the application of CD and increased rice yield by about 1 t ha^{-1} per year over that obtained with chemical fertilizer alone. Over 10 years, the grain yield trend with the control plots was negative, but not significantly, both in the dry and wet seasons. The yield trend was significantly positive in the dry season, but no significant trend was observed in the wet season. The treatments, which showed positive yield trend, also showed positive total P uptake trend. Positive yield trends were attributed to the increasing P supplying power of the soil.

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^{-1} 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^{-1} , respectively than under flooded condition. The highest yield of Zhensan 97B (5.3 t ha^{-1}) was obtained under flooded condition.

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

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.

Mchugh *et al*. (2002) observed highest yield of rice grain was obtained in case of alternate wet and drying system (6.7 t ha^{-1}) than non flooded (5.9 t ha^{-1}) and continuously flooded irrigation (5.9 t ha^{-1}). This result suggest that by combining alternate wet and drying irrigation with system of rice intensification practices, farmers can increase grain yields while reducing irrigation water demand.

Ebrahim *et al*. (2011) conducted an 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^{-1} nitrogen fertilizer consumption.

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.

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.

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 rhizosphere and increased yield of rice.

Aulakh (1996) carried out an experiment in soils with light texture (sandy soil), soil doesn't have high water holding capacity, thus in such a situation irrigation periods may be constant or its frequency increases, however, in deficit irrigation the water amount reduces compared to normal irrigation in each irrigation

He *et al.* (2015) carried out an experiment in a 3.5-year field experimentusing monolith lysimeters cropped with either (i) single paddy rice in the wet season and maize in the dry season(maize-paddy rice, M-MIX), or (ii) double paddy rice (R-WET) as control. Expandable and compressible padsminimized the formation of a gap at the interface between soil monolith and lysimeter casing during shrinking and swelling of the clay soil. In the first year of introducing maize, drainage (606 l m^{-2} yr^{-1}) and leaching of total nitrogen (TN, 6.8 g N m^{-2} yr^{-1}) and DOC (2.7 g m^{-2} yr^{-1}) were significantly larger in M-MIX than in RWET (water: 149 l m^{-2} yr^{-1}, TN: 0.1 g m^{-2} yr^{-1}, DOC: 0.7 g m^{-2} yr^{-1}). However, the additional losses of water, nitrogen, and DOC caused by the introduction of maize disappeared in the following years. In the last two dry seasons of our study, drainage and leaching losses of TN, and DOC were even significantly smaller in M-MIX than in R-WET. In the dry seasons of the 2nd to 4th year after introducing maize (2013–2015), M-MIX saved on average 388 l m^{-2} of percolation water losses compared to R-WET and leaching losses of TN and DOC under maize were reduced on average by 0.6 g m^{-2} and 1.6 g m^{-2}, respectively. They conclude that leaching losses of water and nutrients are only transiently boosted during the first year after introducing maize in perennial rice cropping systems, so that maize cropping in the dry season could save water and reduce nutrient leaching in comparison to continuous paddy-rice cropping in the long run.

Katoh *et al*. (2005) carried out an experiment on impact of water percolation on nutrient leaching from an irrigated paddy field in Japan to know the effect on soil nutrient status and sustainability of water percolation through an irrigated paddy field in Japan. The difference between amounts of nutrients leached by percolation and those supplied by irrigation indicated that 25–130 kg ha^{-1} Ca, 8–24 kg ha^{-1} Mg, from −1 to 9 kg ha^{-1} K, and 8–17 kg ha^{-1} Fe, respectively, were lost each year from the 0–40 cm soil layer during rice cultivation, when the supply from fertilization and rainfall and the loss in grain harvest were not accounted for. When the supply of K from rainfall and the loss in grain harvest were taken into account, a total K loss of about 10 kg ha^{-1} was estimated. The amounts of exchangeable Ca and Mg in the soil to a depth of 40 cm would decrease by 50% within 50–260 and 30–100 years, respectively, if similar management were continued without fertilization.

Pathak *et al.* (2001) carried out an experiment to measure the N leaching to shallow groundwater from a tropical paddy field. The N inputs to and outputs from field were measured by direct method. Inputs of N to the site came from commercial fertilizer, precipitation, irrigation water and soils. Outputs of N from the site were leached to groundwater, harvested crops, in surface runoff, soils and loss from the field. Leaching loss was calculated from daily fluxes of water percolation and soil water N concentration sextracted by vacuum lysimeter. Based on three month observation, average leaching of nitrate nitrogen (NO_3^--N), ammonium nitrogen (NH_4^+-N) and total Kjeldahl nitrogen (TKN)to groundwater was found 0.04, 0.11 and 0.17 kg $ha^{-1}d^{-1}$ respectively. It was also observed that fertilizer application increased NO_3^--N concentration at five-fold in groundwater. Furthermore, nitrogen mass balance result showed that loss of N inputs as outflow to the water and atmosphere were from the 19 % and 13.6% of total applied N respectively which indicates fertilizer input was responsible for water pollution.

Meng *et al.* (2014) conducted an experiment on inorganic nitrogen leaching from organic and conventional rice production on a newly claimed calciustoll in central asia to characterizing the dynamics of nitrogen (N) leaching from organic and conventional paddy fields is necessary to optimize fertilization and to evaluate the impact of these contrasting farming systems on water bodies. They assessed N leaching in organic versus conventional rice production systems of the Ili River Valley, a representative aquatic ecosystem of Central Asia. The N leaching and overall performance of these systems were measured during 2009, using a randomized block experiment with five treatments. PVC pipes were installed at soil depths of 50 and 180 cm to collect percolation water from flooded organic and conventional paddies, and inorganic N (NH_4-N+NO_3-N) was analyzed. Two high-concentration peaks of NH_4-N were observed in all treatments: one during early tillering and a second during flowering. A third peak at the mid-tillering stage was observed only under conventional fertilization. NO_3-N concentrations were highest at transplant and then declined until harvest. At the 50 cm soil depth, NO_3-N concentration was 21–42% higher than NH_4-N in percolation water from organic paddies, while NH_4-N and NO_3-N concentrations were similar for the conventional and control treatments. At the depth of 180 cm, NH_4-N and NO_3-N were the predominant inorganic N for organic and conventional paddies, respectively. Inorganic N concentrations decreased with soil depth, but this attenuation was more marked in organic than in conventional paddies. Conventional paddies leached a higher percentage of applied N (0.78%) than did organic treatments (0.32–0.60%), but the two farming systems leached a similar amount of inorganic N per unit yield (0.21–0.34 kg N Mg^{-1} rice grains). Conventional production showed higher N utilization efficiency compared to fertilized organic treatments. These results suggest that organic rice production in the Ili River Valley is unlikely to reduce inorganic N leaching, if high crop yields similar to conventional rice production are to be maintained.

2.4 Effects of Integrated Nutrient Management on the Yield of rice and soil fertility

Nutrient leaching leading to depletion of soil fertility has arisen due to intensive land use without appropriate soil management. The situation has become worse in areas where HYV crops are being grown using low to unbalanced doses of mineral fertilizers, with little or no organic recycling. Because of increasing cropping intensity and cultivation of modem varieties of crops, the net removal of plant nutrients is far from the nutrient supply through fertilizers and manures. It is reported that the overall N balances of Bangladesh soils are negative depending on the nutrient management and cropping systems, the P balances are near zero and the K balances are highly negative.

Saha *et al.* (2007) studied a 7-years-long field trial was conducted on integrated nutrient management for a dry season rice (Boro)–green manure (GM)–wet season rice (T. Aman) cropping system at the Bangladesh Rice Research Institute Farm, Gazipur during 1993–1999. Five packages of inorganic fertilizers, cow dung (CD), and GM dhaincha (*Sesbania aculeata*) were evaluated for immediate and residual effect on crop productivity, nutrient uptake, soil-nutrient balance sheet, and soil-fertility status. Plant height, active tiller production, and grain and straw yields were significantly increased as a result of the application of inorganic fertilizer and organic manure. Usually, the soil-test-based (STB) fertilizer doses for a high-yield goal produced the highest grain yield of 6.39 t ha^{-1} (average of 7 years) in Boro rice. Application of CD at the rate of 5 t ha^{-1} (oven-dry basis) once a year at the time of Boro transplanting supplemented 50% of the fertilizer nutrients other than nitrogen in the subsequent crop of the cropping pattern. A positive effect of GM on the yield of T. Aman rice was observed. Following GM, the application of reduced doses of phosphorus, potassium, sulfur, and zinc to the second crop (T. Aman) did not reduce yield, indicating the beneficial residual effect of fertilizer applied to the first crop (Boro rice) of the cropping pattern. The comparable yield of T. Aman was also observed with reduced fertilizer dose in CD-treated plots. The total P, K, and S uptake (kg ha^{-1} yr^{-1}) in the unfertilized plot under an irrigated rice system gradually decreased over the years. The highest amount of soil-available S was found in T_{4c}- and T_{4a}-treated plots. It was 2.5 times higher than that of the initial soil. The application of CD and dhaincha GM along with chemical fertilizers not only increased organic C, total N, available P, and available S but also increased exchangeable K, available Zn, available iron, and available manganese in soil.

Islam *et al*. (2012) found that all the cultivars gave some-what better yield under inorganic management where the yield variation was minimum between organic and inorganic management. Conversely, organic culture had beneficial effects in improving soil properties and the sustainable agriculture mostly depends on soil organic matter. This organic matter will remain stable by using organic fertilizer

Ali *et al*. (2003) while working on the development of fertilizer recommendation for the cropping pattern Potato-Boro-*T. aman* in irrigated medium highland condition under AEZ -9 found that recommended fertilizer dose based on the FRG '97 was more economic than all other fertilizer doses for the whole pattern (FRG, 1997). But the treatment Integrated Plant Nutrition Systems based on fertilizer management with cowdung for high yield goal produced the maximum grain and straw yields in the first crop. Application of cowdung had no significant effect on the yield of succeeding crops.
The gap between nutrient removal and supplies is likely to widen further due to a number of reasons like pressure on land, increased demand for cereal food grain, fertilizer availability and price.

Hossain *et al*.(1995) found that the nutrient requirement in near future could not be met by natural sources alone. Mineral fertilizer inputs are the crucial factors to the over all nutrient balance in intensive cropping systems. Organic matter content of most of the soils of Bangladesh is very low (0.8 to 1.8%) as compared to desired (2.5% and above) levels.

Fokhrul and Haque(1998 a, b) studied that fertilizers have been responsible for nearly 50% yield increases registered in recent years. But the current fertilizer use in Bangladesh is highly imbalanced because of its limited availability and unfavourable fertilizer, produce price ratio and its use is rarely decided by local recommendation.

Bhuiya and Akanda (1982) reported that organic materials in combination with chemical fertilizers showed excellent response to rice cultivation. Imbalanced use of inorganic fertilizers and soil nutrient mining has resulted in declining soil fertility and therefore, stagnating or decreasing of crops yields. Balanced fertilization carry different meanings considering the nutrient input-output relationship in soil plant system, ratio of fertilizer products and balanced in cost and return of fertilization.

Sarkar *et al.*(1996) measured that fertilizer is one the most important factors of increasing the productivity of crops. One of the alternatives to economize the use of chemical fertilizers is to incorporate crop residues or apply farmyard manure in combination with chemical fertilizers. Now, it is felt that with the introduction of modern varieties of crops and use of relatively high quantity of fertilizer, it needs to develop fertilizer management practices for proper management of soil health and also for nutrient balanced that is economically viable.

Mannan *et al.* (2000) reported that manuring with cowdung up to 10 t/ha in addition to recommended inorganic fertilizers with late N application improved grain and straw yields and quality of transplant aman rice over inorganic fertilizer alone.

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 Cavegelli (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.

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

Saleque *et al*. (2004) conducted a field experiment to determine the effect of different doses of chemical fertilizers alone or in combination with cowdung 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. They also showed that application of one third of recommended inorganic fertilizers with 5 t cowdung increased the low land rice yield than other treatments and gives yield 8.87t ha^{-1}.

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, grain and straw yields.

Farid *et al*. (1998) carried out an experiment on 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%).

Chittra and Janaki (1999) stated that the application of composted coir pith improves the soil available K status and increases the uptake of K by grain and straw yield of rice. Application of 50 kg N with green leaf manure gave the highest grain and straw yield in both season, followed by composted coir pith.

HDRA(1999) concluded that 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.

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.

Elsharaeay *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 tested 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.

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.

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^{-1} .

Vijay and Singh (2006) was conducted a field experiment during kharif season of 2003 and 2004 at J.V. college, Baraut, Uttar Pradesh, India, to study the effect of organic manures and fertilizer treatments on growth, yield and yield attributes of rice. The manure treatment comprises compost. Fertilizer treatments included N at 0, 40, 80 and 120 kg ha^{-1}. Application of compost significantly improved the growth, yield and yield attributes of rice during the years of experimentation. However, the organic manure compost did not show marked variation among the other treatments. Each unit increase in N levels led to significant increase in growth, yield and yield attributing characters of rice up to 80 kg N ha^{-1} over the during study.

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

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. 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.

Singh *et al*. (2001) studied on the effect of poultry manure under irrigated condition with nitrogen in rice-wheat cropping system in an Alfisol of Bilapur, Madhya Pradesh, India. The treatment consisted of poultry manure alone and in combination with nitrogen fertilizer. Root and shoot biomass at different growth stages increased with the application of N and poultry manure alone and combination. Root and shoot biomass was higher in 100% N through poultry manure, followed by 75% N through poultry manure and 25% through urea.

Vanaja and Raju (2002) conducted afield 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 yields.

Umanah *et al*. (2003) found 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 numbers/panicle and dry grain yield. There was no significant difference among the treatments for 1000-grain weight.

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 maximuma at 3 t poultry manure ha^{-1} . Poultry manure at 2 t ha^{-1} 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. Agronomic efficiency of N (AEN) at 75% NPK (112.5:56.3:56.3 kg NPK ha^{-1}) was equivalent to 2 t poultry manure ha^{-1} . 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.

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 fertilizer 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^{-1} , T_5: 70& NPKS + dhaincha (DH) @ 15t ha^{-1} , T_6: 70% NPKS + mungbean residue (MBR) @ 10t ha^{-1} /ha, T_7: 70% NPKS + cowdung (CD) @ 5t ha^{-1} and T_8: 705 NPKS + poultry manure (PM) @ 3t ha^{-1} . 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 indentical 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^{-1} , which was indentical with the application of 70% NPKS + PM (6.57 t ha^{-1}). The total grain yield in the cropping pattern ranged from 5.14 t ha^{-1} in T_1 (control) treatment to 12.29 t ha^{-1} in the 100% NPKS. The application of 3 t ha^{-1} PM with 70% NPKS (T_8) produced the total yield of 12.09 t ha^{-1} followed by 11.59 t ha^{-1} in the treatment containing 10 t ha^{-1} MBR plus 70% NPKS (T_6). It appears that the application of 3 t ha^{-1} 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.

Mahavisha *et al*. (2004) investigated a field study during the kharif season of 2001 in Andra Pradesh, India to investigate the effect of organic fertilizer sources on the growth and yield of rice. The crop growth and yield were higher with 125% recommended fertilizer + poultry manure and 100% RDF + poultry manure compared to the other treatments.

Miah *et al*. (2004) found 5.6-6 t/ha-grain yields with application of 2 t ha^{-1} poultry manure plus 120 kg N ha^{-1} in Boro season.

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^{-1}) than the control and FYM application at 7.5 t ha^{-1}, significantly improved the soil P and K status, and increased the N content of the soil. 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.

Singh *et al.,*(2005) described that crop residues, usually considered a problem, when managed correctly can improve soil organic matter dynamics and nutrient cycling, thereby creating a rather favorable environment for plant growth. The intelligent management and utilization of crop residues is essential for the improvement of soil quality and crop productivity under rice-based cropping systems of the tropics. Viable option is to retain residue in the field; burning should be avoided. The major issue is adapting drills to sow into loose residues. Strategies include chopping and spreading of straw during or after combining or the use of disc-type trash drills. Residues rich in lignin and polyphenol contents experience the lowest decay. Decomposition of crop residues occurs at a rapid rate—about 80% of crop residue C is lost in the first year—under the warm and humid conditions of the tropics. Factors that control C decomposition also affect the N mineralization from the crop residues. Decomposition of poor-quality residues with low N contents, high C: N ratios, and high lignin and polyphenol contents generally results in microbial immobilization of soil and fertilizer N. Nutrient cycling in the soil–plant ecosystem is an essential component of sustainable productive agricultural enterprise. Although during the last three decades, fertilization practices have played a dominant role in the rice-based cropping systems, crop residues—the harvest remnants of the previous crop still play an essential role in the cycling of nutrients. Incorporation of crop residues alters the soil environment that in turn influences the microbial population and activity in the soil and subsequent nutrient transformations.

Yadab *et al.* (2013) studies Rice–wheat rotations, practiced in 12.5 million ha in Indo-Gangetic Plain Region (IGPR), are the most important production system for food security of south Asian countries. They analyzed the yield trends and effect of fertilizer NPK application, alone or in combination with farmyard manure (FYM), green manure (GM) or wheat crop residue (CR) incorporation, on the changes in soil organic carbon (OC) and available NPK contents. Data of a long-term experiment conducted at six locations in the

IGPR and at one location in the Central Highlands and Plateau region of India, adjacent to IGPR, revealed that yields of rice and wheat were constantly greater in all the years when complete doses of NPK were applied through fertilizers, or 50% dose of NPK were applied through fertilizers along with organic materials compared to that in unfertilized-control. The increase in yield of rice with integrated supply of nutrients through fertilizers and manures, indicating thereby the advantage of combined use of manures plus fertilizers over fertilizers alone in sustaining crop yields. Soil OC decreased over time at locations where the OC content was greater than 6.5 g kg^{-1} at the start of the long-term experiment, but increased at locations having initially low (<5.0 g kg^{-1}) OC content. Available P content increased with P additions through fertilizers or manures at four locations. Temporal changes in available P content, however, appeared to have depended on the changes in soil OC.

Moe *et al.* (2017 a)investigated the effect of combining organic and inorganic fertilizers on the growth and yield of hybrid rice (Palethwe-1) in the dry and wet seasons of2015. Four quantities of inorganic fertilizer were used in the main plot [0%,50%, 75%, and 100% nitrogen, phosphorus, and potassium (NPK)] based on the recommended amounts of 150 kg N ha^{-1}, 70 kg P_2O_5 ha^{-1}, and 120 kg $K_2O$$ha^{-1}$, while different organic manures were applied to subplots [no organic manure, cow manure, poultry manure, and vermicompost; all at 5 t ha^{-1}] as part of a split-plot experimental design with three replications. The 100% NPK (I_{100}) fertilizer produced the maximum yield but similar yields were achieved in plots supplied with 50%NPK (I_{50}) and 75% NPK (I_{75}). This study demonstrates that the combined application of inorganic fertilizers and organic manures has the potential to reduce chemical fertilizer usage without decreasing the yield of hybrid rice, and can enhance the growth, yield, and yield components of Palethwe-1.

Moe *et al.* (2017 b) conducted two field experiments to investigate combined effects of organic and inorganic fertilizers on nitrogen use and recovery efficiencies of hybrid rice (Palethwe-1) during dry and wet seasons, 2015. Four levels of inorganic fertilizer (0%, 50%, 75%, and 100% NPK), based on recommended rates of 150 kg N ha^{-1}, 70 kg P_2O_5 ha^{-1}, and 120 kg K_2O ha^{-1}, were used with cow manure, poultry manure, and vermicompost (5 tha^{-1}each) in a split-plot design with three replications. In both seasons, with 50% NPK, the N uptake level achieved with poultry manure was similar to that obtained with 75% and100% NPK. The greatest N use, internal, agronomic N use, and recovery efficiencies were obtained with 50% NPK + poultry manure, but were similar to those obtained from cow manure and vermicompost subplots. As the amount of applied N from organic and inorganic fertilizer increased, the N use efficiency and related parameters decreased, due to similar yields among plots with different NPK application levels. Poultry manure resulted in the highest significant correlations between applied N and N accumulation, followed bycow manure and vermicompost, in both seasons. Neither chemical fertilizer nor organic manure alone led to optimum N use and N recovery efficiencies. The combination of 50% inorganic fertilizer (75 kg N ha^{-1}) and poultry manure(5 t·ha^{-1}) enhanced the N uptake, the N use and recovery efficiencies of hybrid rice.

Islam *et al.* (2014) conducted a field experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh during Aman season of 2011 to evaluate the effects of manures and fertilizers for maximizing the yield of BRRI dhan49. The treatments were T_0 = Control, T_1 = STB-CF (HYG), T_2 = CD + STB-CF (HYG), T_3 = PM + STB-CF(HYG), T_4= CoM + STB-CF (HYG) and T_5 = Farmers' practice (FP). Organic manures including cowdung, poultrymanure and compost were applied to the experimental plots @ 5, 3 and 5 t ha^{-1}, respectively. The recommended dozes ofN, P, K and S supplied from urea, TSP, MoP and gypsum were 90, 15, 60 and 15 kg ha^{-1}, respectively. Yield contributing characters like plant height, effective tillers $hill^{-1}$, panicle length and grains panicle-1 of BRRI dhan49 were significantly influenced by the application of manures and fertilizers. The highest grain yield of 4.87 t ha^{-1} was observed in the treatment T_3[PM + STB-CF (HYG)] and the lowest value of 3.61 t ha^{-1} was found in T_0 (control). The straw yield ranged from 4.10 to5.51 t ha^{-1} in different treatments. The NPKS uptake by BRRI dhan49 was markedly influenced by manures and fertilizers. Based on overall results, the treatment T_3 [PM + STB-CF (HYG)] was found to be the best combination of manures and fertilizers for obtaining the maximum yield and quality of rice.

Rouf *et al.* (2011**)** conducted an experiment at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka in aman season to find out effect of fertilizer and manure on the 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- Factors A: Soils from different location (soil from 2 locations), S_1: SAU soil, S_2: Shingair soil (collected from Shingair Manikgonj) and Factor B: Levels of fertilizers and manures (5 levels), T_0: Control condition i.e. no fertilizers and manures; T_1: Recommended dose of fertilizer ($N_{120}P_{25}K_{60}S_{20}Zn_2$), T_2: 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}. Due to the interaction of soil from different location and fertilizers and manure, the highest grain yield (134.97 g pot^{-1}) was found from S_2T_4, whereas the lowest grain yield (32.03 g pot^{-1}) was recorded from S_1T_0. Shingair soil and 50% NPKSZn + 3.5 ton poultry manure ha^{-1} performed better in relation to yield contributing characters and yield of BRRI dhan33.

Applied nutrients are rapidly leached below the root zone of annual crops (Cahn et al., 1993; Melgar *et al*., 1992) and large amounts of nitrate (NO_3^-) were found to accumulate in acid subsoils (Cahn *et al*., 1992). In order to increase nutrient use efficiency, techniques must be developed to keep applied nutrients in the topsoil and therefore in the main root zone of the crop. Two basic approaches can be used to reduce nutrient leaching; applying slow-release nutrient forms such as organic fertilizers and increasing adsorption 344 sites thereby retaining applied inorganic nutrients. Animal manures and composts have shown in several trials to increase nutrient availability and to partly substitute mineral fertilizers (Goyal *et al*., 1999). How well organic amendments are effective for supplying sufficient nutrients for plant growth and for reducing leaching of applied mineral nutrients under high leaching conditions is far less clear. Additionally, organic fertilizers may mineralize rapidly and therefore have to be applied repeatedly to maintain sufficient available nutrients and exchange capacity.

Yanan *et al.* (1980) carried out an experiment on Effect of organic manure and chemical fertilizer on nitrogen uptake and nitrate leaching in a Eum-orthic anthrosols profile to know Distribution and accumulation of NO_3^--N down to 4mdepth in the soil profile of a long term fertilization experiment with organic manure and N and P chemical fertilizer were studied after 12 years, wheat and corn were planted in each year. The apparent N recovery decreased with increased N and P fertilizer. NO_3^--N was mainly accumulated in 0-1.2 m depth of the soil profile with a maximum of 34 mg N kg^{-1} for the treatment with 120 kg N and 26 kg P per hectare, a secondary maximum of 7.2 mg N kg^{-1} was found at 3.2 m depth in the same treatment. NO_3^--N accumulation in the soil profile was minimized in the trials with highest manure application. Nitrogen that was not recovered was leached as NO_3^--N deeper than 4 m depth, was immobilized in the profile or was lost by denitrification.

Iqbal (2010) conducted an experiment to determine the effects of five fertilizer application rates on N vertical leaching from 30 and 60 cm soil layers. Results showed that during the paddy growth NH_4^+- N was the main form of nitrogen with a high environment risk. The range of NH_4^+- N / TN varied from 0.27- 0.89 with NH_4^+- N concentration peak appearing within 2-4 days after three fertilizer application rates; the highest NH_4^+- N concentrations were about 38.38 mg L^{-1} for the 360 kg ha^{-1} or N_4 treatment. Significant differences were observed in the two layers between the other four fertilizer application rates. Nitrate concentrations at 30 cm depth soil leachate were higher than at 60 cm depth; however, the peak of about 9.21 mg L^{-1} for the 30 cm depth soil leachate appeared 1-2 days later than the NH_4^+- N and the concentrations for the 60 cm soil layer leachate which was less than 3 mg L^{-1}. Nitrogen loss from different nitrogen treatments varied from 2.82 to 5.07 % of the urea based fertilizer applied. The cumulative effects of nitrate leaching on the quality of the shallow ground water should be of concern.

CHAPTER 3

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Three experiments were conducted at the Soil Science Department and research field of Sher-e-Bangla Agricultural University during January 2013 to June 2014 to study the effects of fertilizer, manure and water management on the nutrient availability, leaching, soil fertility and productivity under rice-rice cropping pattern. A brief description on the soil, crop, layout of the experiment, treatments under investigation, cultural operations, collection of soil and crop samples and analytical methods followed have been presented in this chapter.

3.1 (Experiment 1) Effects of fertilizer, manure and irrigation on nutrient contents in leachate and yield of rice

3.1.1 Experimental Site

The experiment was conducted at the net house of Soil Science Department of Sher-e-Bangla Agricultural University (SAU), Dhaka. Two crops (Boro- T.aman) were grown in the same core during January, 2013 to December, 2013. The university area belongs to the Madhupur Tract (AEZ 28) having $28^{\circ}74'$ N latitude and $90^{\circ}35'$ E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season January 2013 to December 2013 have been presented in Appendix I.

3.1.3 Soil Core Collection

A total 30 (2 irrigation x 5 fertilizer and manure x 3 replications) undisturbed soil cores (25 cm diameter and 40 cm length) were collected in the PVC pipe and placed on the plastic containers in the net house. Initial soil samples were collected from 0- 10 cm depth. The soil collection area of SAU is located at 24.75 latitude and 90.50^{0}E longitude.

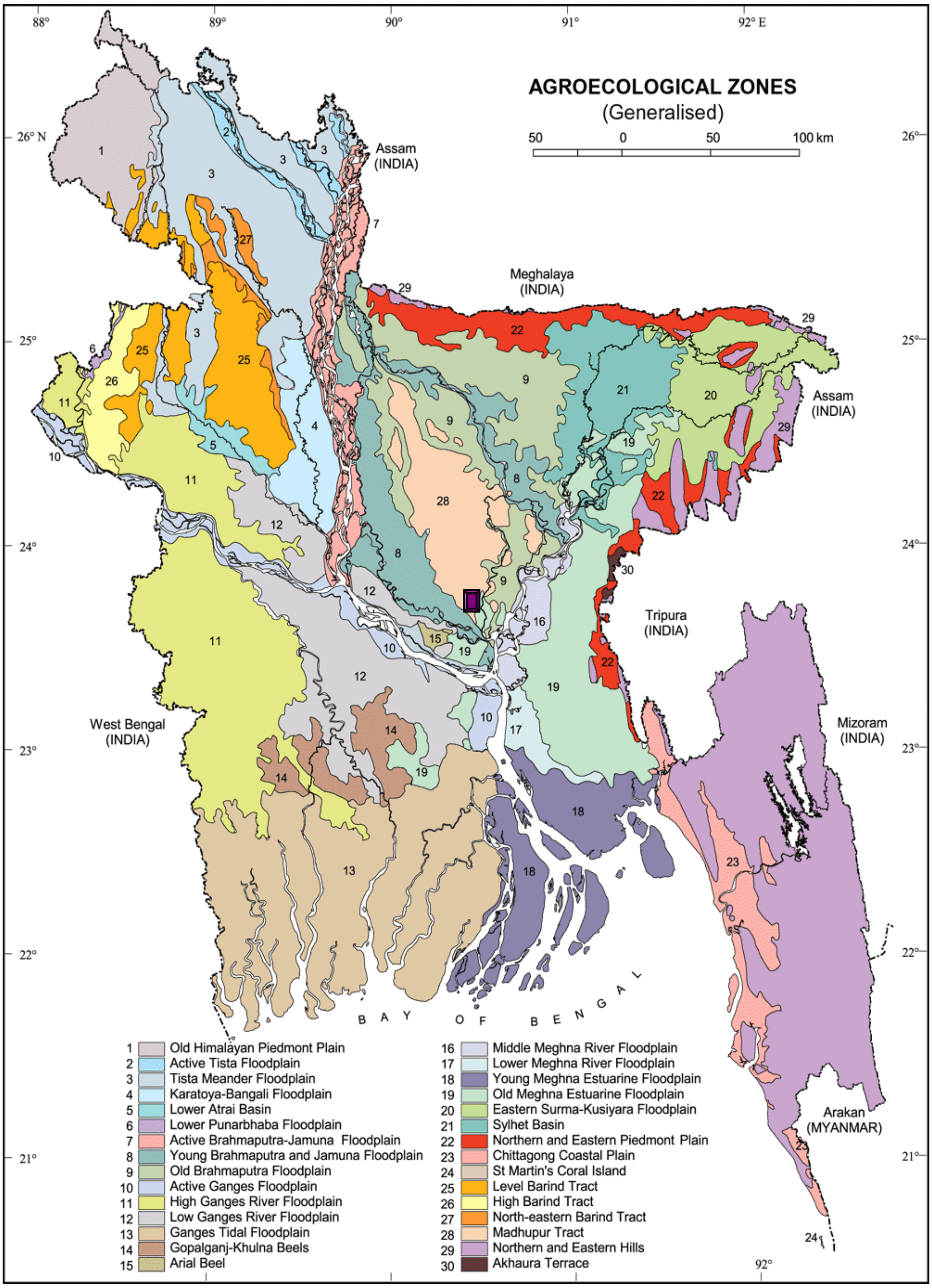


Figure 3.1 Map showing the experimental sites under study

Table 3.1.1 Physical and Chemical Properties of Soil

Characteristics	Value
Textural class	Silt loam
pH	6.1
Organic C (%)	0.77
Total N (%)	0.073
Exchangeable K (cmol kg^{-1})	0.13
Available P (mg kg^{-1})	17.72
Available S (mg kg^{-1})	13.5

3.1.4 Experimental set-up

Soil cores were placed on the plastic containers. Whatman filter papers, glass wool and a layer of (2 cm) acid washed silica sand sieved to 1-2 mm were placed at the bottom of the perforated plastic containers where soil cores were placed. Two holes of the plastic container were connected with a conical flask by two plastic pipes via glass T tube (Fig. 3.2). Two glass tubes were inserted through the cork placed on the neck of the conical flask, grease was used for make it air tight. Then, the long glass tube of the conical flask was connected with the holes of the plastic container by plastic pipe via glass T tube.

3.1.5 Leachate collection

A net house experiment involving 2 levels of irrigation and 5 fertilizer treatments were applied in undisturbed soil columns during January 2013 to December 2013, with boro and T. aman grown season in sequence to examine the effect of added fertilizer and manure on rice culture. This experiment was started during boro rice season of the year 2013. Fertilizer, manure and irrigation treatments were applied in the soils of the core during the boro and T. aman rice cultivation.

3.1.6 Experimental Design and Layout

This experiment was laid out in Randomized Complete Block Design (RCBD) having three replications. The layout of the experiment has been shown in Fig. 3.3.

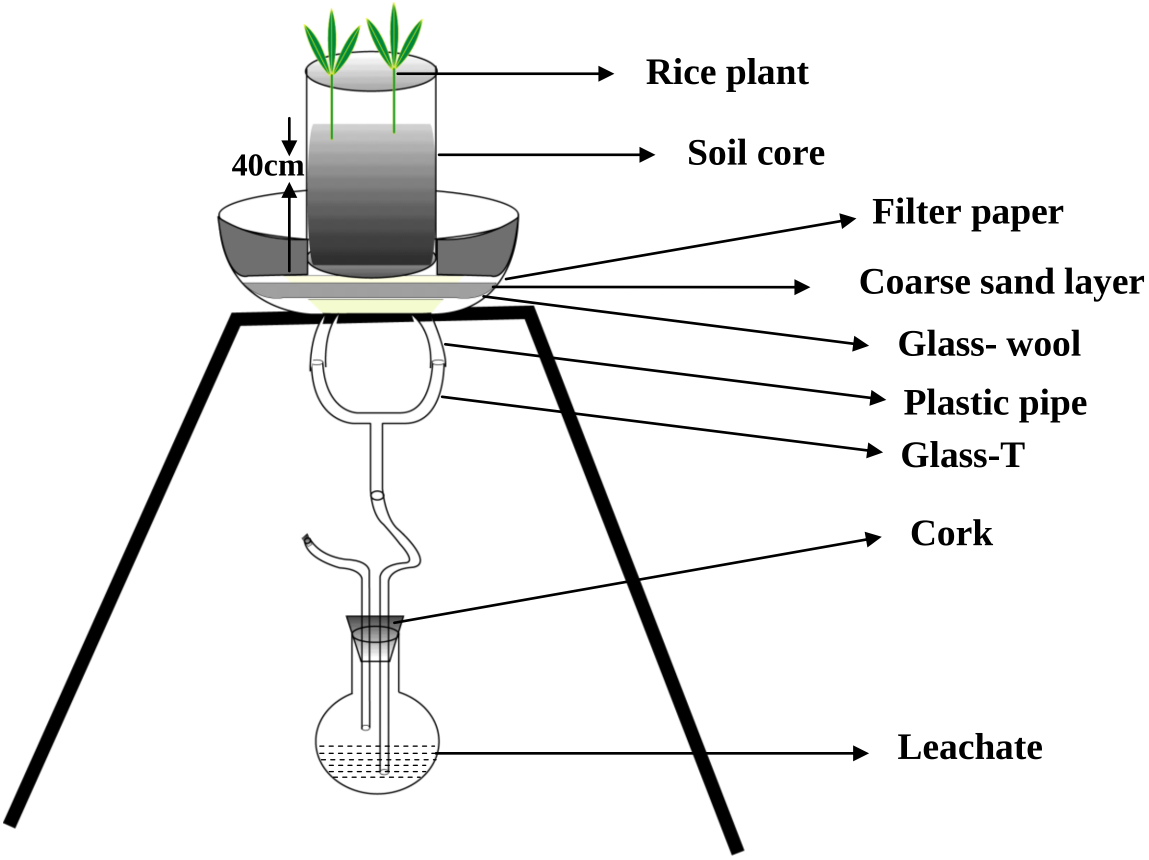


Figure 3.2 Leachate collection system from undisturbed soil core applied with fertilizer and manure application.

3.1.7 Treatments, Transplantation, Irrigation Management, Fertilizer application and Leachate Collection

2 levels of irrigation and 5 levels of fertilizer and manure treatment were applied in the soil of the core in both season. Recommended fertilizer dose for boro rice was $N_{120}P_{25}K_{60}S_{20}Zn_2$ and that for T. aman rice was $N_{100}P_{15}K_{45}S_{12}Zn_2$.

Factor A- 2 Levels of Irrigation

I_1= Traditional irrigation

I_2= Saturated condition

Factor B: 5 Fertilizer and Manure Treatment

T_0 = Control

T_1 = Recommended dose of fertilizer

T_2 = 50% NPKSZn + 5 ton cowdung ha^{-1}

T_3 = 50% NPKSZn + 5 ton compost ha^{-1}

T_4= 50% NPKSZn + 3.5 ton poultry manure ha^{-1}

Table 3.1.2 Nutrient concentrations in cowdung, poultry manure and compost (Oven dry basis)

Sources of organic manure	Nutrient content (%)			
	N	P	K	S
Cowdung	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

3.1.8 Planting material

BRRI dhan29 was used as the test crop in *boro* season and BRRI dhan33 was used as the test crop for T. aman season. These two varieties were developed at the Bangladesh Rice Research Institute (BRRI).

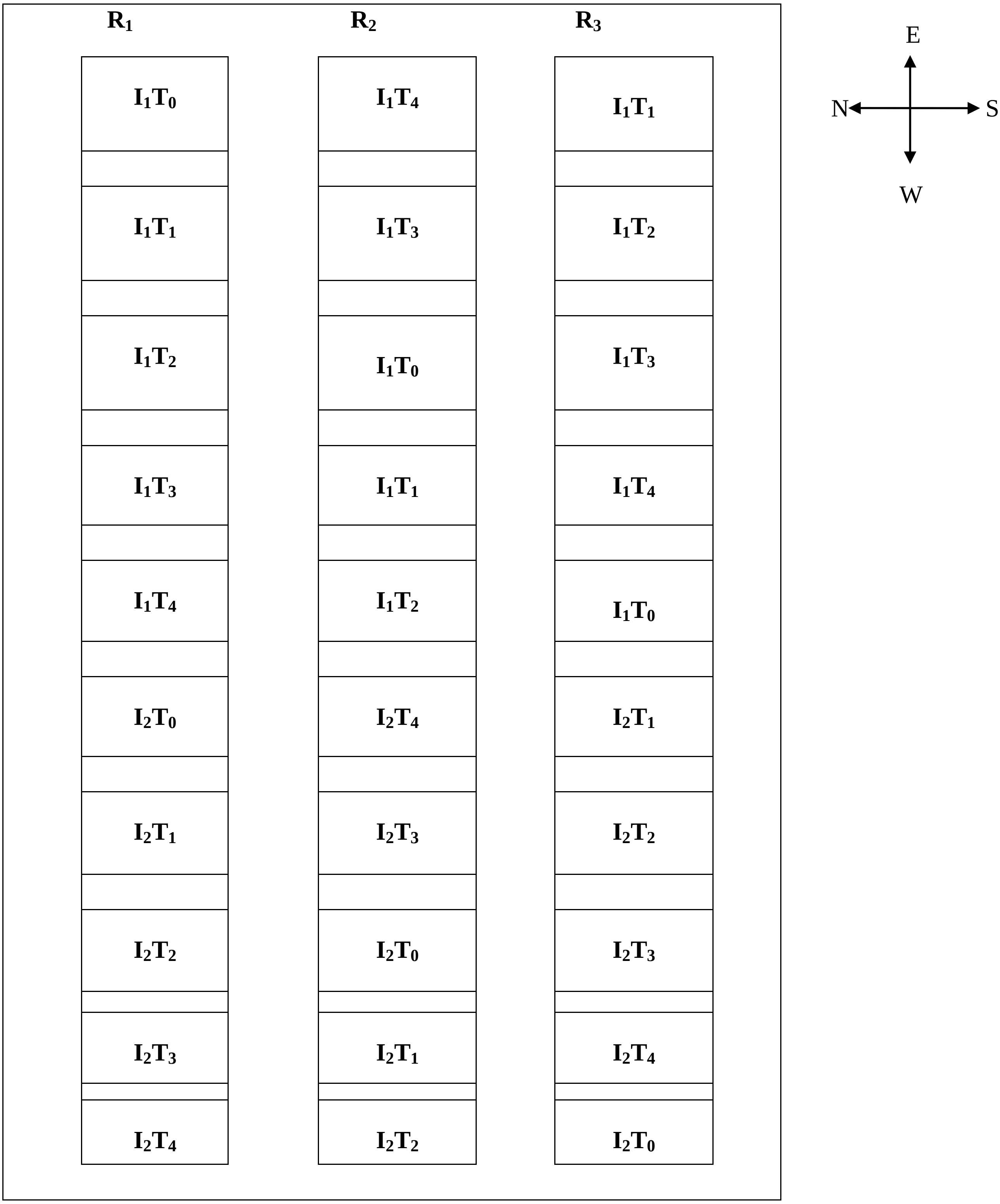


Figure 3.3 Layout of the experiment 1

3.1.9 Initial and post-harvest soil sampling

Initial soil samples were collected from 0- 10 cm depth at 10 cm intervals from SAU campus. The post-harvest soil samples were collected from the soil cores upto 0-10 cm depth at 10 cm intervals. The composite soil samples 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.

3.1.10 Fertilizer and Manure Application

Fertilizer and manure treatments were applied in the soils of the core during both boro and T. aman cultivation in net house. The fertilizer and manures were mixed in the soils of the core and inside the core up to 15 cm depth of the soil before transplanting the seedlings into the core. Similar treatments were applied during boro and T.aman season. Recommended dose of fertilizer was calculated according to FRG 2012. During boro and T. aman seasons all types of fertilizer and manure were applied. During T. aman growing season, the crop was grown in rain-fed condition in soil and recommended dose ($N_{100}P_{15}K_{45}S_{12}Zn_2$) of inorganic fertilizers and manures were applied. During boro growing season recommended dose ($N_{120}P_{25}K_{60}S_{20}Zn_2$) of inorganic fertilizers and manures were applied. The treatment wise required amounts of manures and N, P, K and S fertilizers per core were applied by considering the soil weight of 0-15 cm depth. Full amounts of manure, TSP, MoP and gypsum were applied at final land preparation 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). Chemical compositions of manures have been presented in Table 3.1.2. Treatment wise irrigation levels were maintained in T. aman season when supplemental irrigation was required.

3.1.11 Raising of seedlings

The seedlings of rice were prepared in raised wet-bed methods. Seeds (95% germination) @ 5 kg/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.

3.1.12 Transplanting

40 days old seedlings of BRRI dhan29 were carefully uprooted from the seedling nursery and transplanted on 1st week of January, 2013 in Boro season. After harvest of boro rice, T. aman rice was transplanted in the same cores. 30 days old seedlings of BRRI dhan33 were carefully uprooted from the seedling nursery and transplanted on 1st week of July, 2013 in T. aman season. Two seedlings for one hill were transplanted in the core in both season. After one week of transplanting all soil cores were checked for any missing seedlings, which were filled up with extra seedlings whenever required.

3.1.13 Irrigation

Traditional irrigation (2-3 cm continuous flooding) and saturated irrigation were applied on the soils of the core as and when required during the growing period of Boro and T. aman rice crop.

3.1.14 Leachate sample collection

Leachate samples were collected at 20, 40 and 60 days after transplantation of both boro and T. aman rice and analyzed for N, P, K and S by using standard analytical method.

3.1.15 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.

3.1.16 Weeding

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

3.1.17 Insect and pest control

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

3.1.18 Crop Harvesting and Data Collection

The net house boro rice (1st crop) was harvested during June, 2013, the yield and yield components were recorded. The net house of T. aman crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on November, 2013. The yield and yield components were recorded. The crops were cut at the ground level. After harvest, the rice yield parameters and yield were recorded. The grain samples were also analysed for N, P, K and S contents.

3.1.19 Yield components

3.1.19.1 Total no. of effective tiller/core and hill

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

3.1.19.2 Plant height

The height of plant was recorded in centimeter at harvesting stage. Data were recorded as the average of 10 plants selected at random from the core and hill. The height was measured from the ground level to the tip of the panicle.

3.1.19.3 Length of panicle

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

3.1. 19.4 No. of filled grains per panicle

The total number of filled grains were calculated from selected 10 plants of a core on the basis of grain in the spikelet and then average numbers of filled grain per panicle was recorded.

3.1. 19.5 Weight of 1000 seeds

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

3.1.19.6 Straw yield

Straw obtained from each core was sun-dried and weighed carefully. The dry weight of straw of the respective core yield was calculated in g core^{-1}.

3.1. 19.7 Grain yield

Grains obtained from each core was sun-dried and weighed carefully. The dry weight of grains of the respective core yield was calculated in g $core^{-1}$.

3.1. 19.8 Boro rice (BRRI dhan29) cultivation

Boro rice (BRRI dhan29) was grown in the cores during January-June, 2013. The yield and yield parameters were recorded. Then the grain samples were analyzed for N, P, K and S by standard methods.

3.1. 19.9 T.Aman rice (BRRI dhan33) cultivation

T.Aman rice (BRRI dhan33) was grown in the same cores during June- November, 2013 to know the residual effects and renewed application of fertilizer treatment during June-November, 2013. The yield and yield parameters were recorded by similar way. Then the grain samples were analyzed for N, P, K and S by standard methods.

3.1.20 Post Harvest Soil Collection and Preparation

After harvest of Boro and T.Aman rice (BRRI dhan29 and BRRI dhan33), the post-harvest soil samples were collected from the soil cores upto 40 cm depth at 10 cm intervals. After harvest of Boro and T.Aman rice (BRRI dhan29 and BRRI dhan33), the post-harvest soil samples were collected from the core upto 40 cm depth at 10 cm intervals. Soil samples of each core were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.1.21 Soil Analysis

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

3.1.21.1 Textural class

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

3.1.21.2 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 (Jackson, 1962).

3.1.21.3 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 7 ml H_2SO_4 were added. The flasks were swirled and heated 160 ^{0}C and added 2 ml H_2O_2 and then heating at 360 ^{0}C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 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 was 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. Sufficient amount of 10N-NaOH solutions was added in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

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

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.1.21.4 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 the standard P curve (Page *et al*. 1982).

3.1.21.5 Available potassium

Exchangeable K 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).

3.1.21.6 Available sulphur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al*. 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength.

3.1.22 Water sample analysis

Leachate samples were analyzed for chemical characteristics viz. total N and available P, K, and S contents. The leachate samples were analyzed by the following standard methods:

3.1.22.1 Total nitrogen

Total N content of leachate samples were determined followed by the Micro Kjeldahl method. Ten ml leachate sample 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. Sufficient amount of 10N-NaOH solutions was added 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 volume in milliliter

3.1.22.2 Inorganic phosphorus

Phosphorus in the leachate was 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 the standard P curve (Page *et al*. 1982).

3.1.22.3 Inorganic potassium

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

3.1.22.4 Inorganic sulphate

Inorganic S content in leachate sample was determined by turbidimetrically described by (Page *et al*. 1982). The pore water S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength.

3.1.23 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 dhan29 and BRRI dhan33. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.2 (Experiment 2) Integrated use of organic and inorganic fertilizer on nutrient in pore water, yield contributing character and yield of rice under traditional and saturated irrigation condition

3.2.1 Experimental Site

The experiment was conducted in the field of experimental farm at Sher-e-Bangla Agricultural University (SAU), Dhaka during January, 2014 to June, 2014. The university area belongs to the Madhupur Tract (AEZ 28) having $28^{\circ}74'$ N latitude and $90^{\circ}35'$ E longitude with an elevation of 8.2 meter from sea level.

Table 3.2.1 Morphological Characteristics of the Experimental Field

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

(FAO and UNDP, 1988)

3.2.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season January 2014 to June 2014 have been presented in Appendix I.

3.2.3 Experimental set-up

A field experiment involving 2 irrigations and 8 fertilizers were applied into the PVC core and outside the core during January 2014-June 2014, with Boro grown season in sequence, to examine the effect of added fertilizer and manure on rice culture. This experiment was started during Boro rice season of the year 2014. A total 48 PVC cores (2 irrigation x 8 fertilizer x 3 replication) were installed upto 40 cm depth in the middle of each plot. Initial soil samples were collected from 0-15 cm depth.

Table 3.2.2 Physical and Chemical Properties of Soil

Characteristics	Value
Textural class	Silt loam
pH	6.4
Organic matter (%)	1.12
Total N (%)	0.08
Exchangeable K (mg kg^{-1})	22.0
Available P (mg kg^{-1})	12
Available S (mg kg^{-1})	8.06

3.2.4 Experimental Design and Layout

The experiment was laid out in split plot design with a distribution of irrigation to the main plots and fertilizers to the sub plots having 3 replications. The layout of the experiment has been shown in Fig. 3.4.

3.2.5 Treatments, Fertilizer application, Transplantation, Irrigation Management, and Leachate Collection

Factor A: 2 Level of Irrigation in the Main Plot

I_1= Traditional irrigation

I_2= Saturated condition

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

T_0 =Control

T_1 =$N_{120}P_{25}K_{60}S_{20}Zn_2$ (Recommended dose of fertilizer).

T_2 =50% NPKSZn + 5 ton cowdung ha^{-1}

T_3 =70% NPKSZn + 3 ton cowdung 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}

T_7 =70% NPKSZn + 2.1 ton poultry manure ha^{-1}

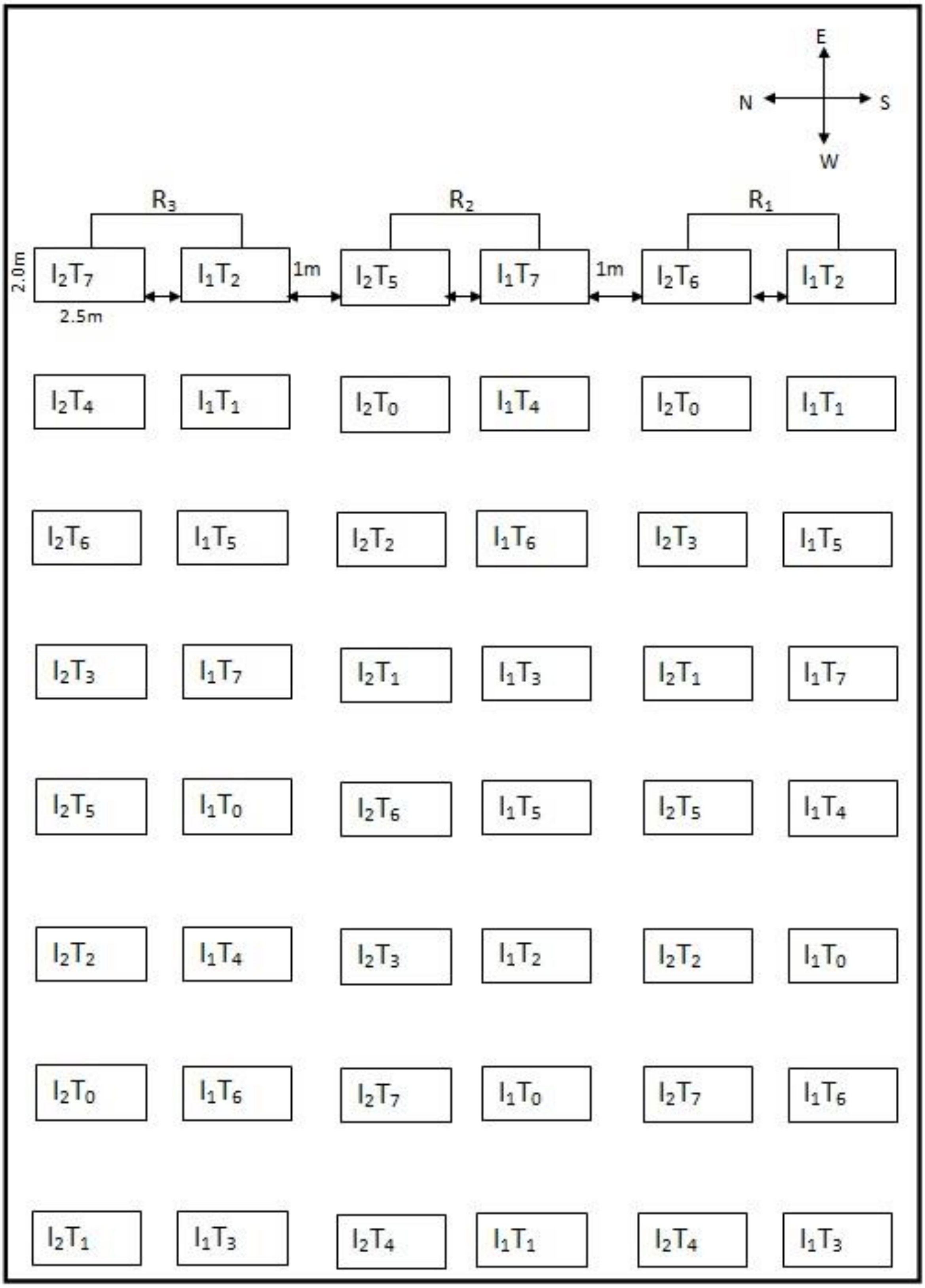


Figure 3.4 Layout of the experiment 2

3.2.5.1 Planting material

BRRI dhan29 was used as the test crop in this experiment. It is recommended for *Boro* season. This variety was developed at the Bangladesh Rice Research Institute (BRRI).

3.2.5.2 Fertilizer and Manure Application

Fertilizer and manure treatments were applied in the soils of the core and outside the core during boro cultivation in field experiment. Cowdung, compost, and poultry manures were applied before four days of final land preparation. The TSP, MP, gypsum and one third urea were applied during final land preparation. The fertilizer and manures were mixed in the soils of outside the core and inside the core up to 15 cm depth of the soil before transplanting the seedling of a plot. During boro season all types of fertilizer and manure were applied. The treatment wise required amounts of manures and N, P, K and S fertilizers were applied in the plots. Full amounts of manure, TSP, MoP and gypsum were applied at final land preparation before transplanting of rice seedlings. Urea were 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). The level of nutrient present in the manures used have been presented in Table 3.3. The nutrient concentrations in the manure are mentioned in Table 3.1.2.

3.2.5.3 Raising of seedlings

The seedlings of rice were prepared in raised wet-bed methods. When seeds (95% germination) @ 5 $kgha^{-1}$ 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.

3.2.5.4 Transplanting

40 days old seedlings of BRRI dhan29 were carefully uprooted from the seedling nursery and transplanted on 1st week of January, 2014 in boro season. Two seedlings for one hill (BRRI dhan29) were transplanted in the plot following a spacing of 20 cm x 20 cm. After one week of transplanting all plots were checked for any missing seedlings, which was filled up with extra seedlings whenever required.

3.2.5.5 Irrigation

Traditional irrigation (2-3 cm continuous flooding) and saturated irrigation were applied on the soils of the experimental field as and when required during the growing period of Boro rice crop.

3.2.5.6 Pore water sample collection

Pore water was collected by using rhizon sampler (Rhizon MOM 10 cm length, 2.5 mm OD, Rhizosphere Research Products, Wageningen, and The Netherlands). It was buried diagonally in the middle of the soil of each pot for collecting soil solution. Pore water samples were collected from outside and inside the core at 20, 40 and 60 days after transplantation of Boro rice and analyzed for N, P, K and S by using standard analytical method.

3.2.6 Intercultural operations

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

3.2.6.1 Weeding

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

3.2.6.2 Insect and pest control

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

3.2.7 Crop Harvesting and Data Collection

The crops were cut at the ground level. The Boro rice was harvested during June, 2014, the yield and yield components were recorded. The yield and yield components were recorded.

3.2.8 Yield components

The data of yield and yield components were recorded according to the methodology described in the section 3.1.19.

3.2.9 Boro- rice cultivation

Before cultivation of Boro rice during January – June, 2014, Boro -T. Aman rice were grown on the same plots with a sequence of Boro- T. Aman rice cropping pattern from 2012. The yield and yield parameters were recorded. After completing five crop cultivation (Boro –T. aman) the post experiment soils were collected and analysed for chemical properties for making the comparison with the initial and post experiment soil properties.

3.2.10 Post Harvest Soil Collection and Preparation

After harvest of Boro rice (BRRI dhan29), the post-harvest soil samples were collected from the plots. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the chemical properties of soil.

3.2.11 Soil and pore water Analysis

Soil samples were analyzed for chemical characteristics viz. pH, total N and available P, K, and S contents. The soil and water samples were analyzed by the following standard methods as described in the 3.1.21 and 3.1.22.

3.3 (Experiment 3) Integrated use of fertilizer and manure on rice yield, soil fertility and nutrient availability under different irrigation management system in rice – rice cropping pattern

3.3.1 Experimental Site

The experiment was conducted in the experimental field farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during July, 2013 to June, 2014. The university area belongs to the Madhupur Tract (AEZ 28) having $28^{\circ}74'$ N latitude and $90^{\circ}35'$ E longitude with an elevation of 8.2 meter from sea level. Morphological characteristics of the experimental field was described in Table 3.2.1. Physical and chemical properties of soil was described in Table 3.2.2.

3.3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season January 2014 to June 2014 have been presented in Appendix I.

3.3.3 Experimental Design and Layout

The field experiment was conducted at Sher-e-Bangla Agricultural university farm during July 2013 to June 2014. The experiment was laid out in split plot design with a distribution of irrigation to the main plots and fertilizers to the sub plots having 3 replications. The layout of the experiment has been shown in Fig. 3.5.

3.3.4 Treatments, Transplantation, Irrigation Management and Fertilizer application

Factor A: 3 Levels of Irrigation in the Main Plot

I_1= Traditional irrigation (continuous flooding)

I_2= Saturated condition

I_3= Alternate wetting and drying

Factor B: 8 Fertilizer and Manure Treatments in the Sub Plot

T_0 =Control

T_1 =$N_{120}P_{25}K_{60}S_{20}Zn_2$ (Recommended dose of fertilizer).

T_2 =50% NPKSZn + 5 ton cowdung ha^{-1}

T_3 =70% NPKSZn + 3 ton cowdung 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}

T_7 =70% NPKSZn + 2.1 ton poultry manure ha^{-1}

3.3.4.1 Planting material

BRRI dhan33 was used as the test crop in T. aman season and BRRI dhan29 was used as the test crop in for boro season. These varieties were developed at the Bangladesh Rice Research Institute (BRRI).

3.3.4.2 Initial soil sampling

Initial soil samples were collected from 15 cm depth of the experimental field. The composite soil samples were air-dried, crushed and passed through a 2 mm (10 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

R_1			**R_2**			**R_3**		
I_1T_0	I_2T_7	I_3T_2	I_1T_1	I_2T_6	I_3T_3	I_1T_2	I_2T_5	I_3T_4
I_1T_1	I_2T_6	I_3T_3	I_1T_3	I_2T_5	I_3T_4	I_1T_6	I_2T_1	I_3T_5
I_1T_2	I_2T_5	I_3T_4	I_1T_5	I_2T_4	I_3T_6	I_1T_3	I_2T_3	I_3T_3
I_1T_3	I_2T_4	I_3T_5	I_1T_7	I_2T_1	I_3T_7	I_1T_5	I_2T_6	I_3T_2
I_1T_4	I_2T_3	I_3T_6	I_1T_2	I_2T_2	I_3T_5	I_1T_0	I_2T_7	I_3T_7
I_1T_5	I_2T_2	I_3T_7	I_1T_6	I_2T_3	I_3T_0	I_1T_7	I_2T_4	I_3T_1
I_1T_6	I_2T_1	I_3T_0	I_1T_4	I_2T_0	I_3T_2	I_1T_1	I_2T_2	I_3T_6
I_1T_7	I_2T_0	I_3T_1	I_1T_0	I_2T_7	I_3T_1	I_1T_4	I_2T_0	I_3T_0

Figure: 3.5 Layout of the experiment 3

3.3.4.3 Fertilizer and Manure Application

Fertilizer and manure treatments were applied in the soils of the 72 plots (3 irrigation x 8 fertilizers x 3 replications) during both boro and T. aman rice cultivation. Cowdung, compost, and poultry manures were applied before four days of final land preparation. TSP, MoP, gypsum and one third urea were applied during final land preparation. The fertilizer and manures were applied in the soils up to 15 cm depth of the soil before transplanting the seedling of a plot. During boro season all types of fertilizer and manure were applied but during T.aman growing season, the crop was grown in rainfed condition without any manure application in soil but recommended dose of inorganic fertilizers were applied. The treatment wise required amounts of manures and N, P, K and S fertilizers per core were applied by considering the area of the plot. Full amounts of manure, TSP, MP and gypsum were applied at final land preparation 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). Chemical compositions of manures used have been presented in Table 3.2.3.

3.3.4.4 Raising of seedlings

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

3.3. 4.5 Transplanting

During T. aman season, 30 days old seedling of BRRI dhan33 were carefully uprooted from the nursery and transplanted on July 2013 in the field. 40 days old seedlings of BRRI dhan29 were carefully uprooted from the seedling nursery and transplanted on 1st week of January, 2014 in boro season. Two seedlings for one hill (BRRI dhan29) were transplanted in the plot. After one week of transplanting all soil plots were checked for any missing seedlings, which were filled up with extra seedlings whenever required.

3.3.4.5 Irrigation

Traditional irrigation (2-3 cm continuous flooding), saturated irrigation and alternate wetting and drying irrigation were applied on the soils of the experimental field as and when required during the growing period of rice crop.

3.3.5 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.

3.3.5.1 Weeding

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

3.3.5.2 Insect and pest control

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

3.3.6 Crop Harvesting and Data Collection

The T.aman (1^{st} crop) was harvested during November, 2013.The yield and yield components were recorded. The Boro rice was harvested during June, 2014. The yield and yield components were recorded. The crops were cut at the level. After harvest, the rice yield parameters and yield were recorded. The grain samples were also analysed for N, P, K and S contents.

3.3.7 Yield components

The data of yield and yield components were recorded according to the methodology described in the section 3.1.19.

3.3.8 T. aman and Boro rice (BRRI dhan33 and BRRI dhan29) cultivation

T. aman rice (BRRI dhan33) was cultivated in the field during July, 2013 –November, 2013. After harvesting of T. aman rice, boro rice (BRRI dhan-29) was grown in the field during January-May, 2014. The yield and yield parameters were recorded by similar way.

3.3.9 Post Harvest Soil Collection and Preparation

After harvest of boro rice (BRRI dhan29), the post-harvest soil samples were collected from different plots of the field upto 15 cm depth. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the chemical properties of soil.

3.3.10 Soil Analysis

Soil samples analytical methods were mentioned in the section 3.1.21.

3.3.11 Statistical analysis

The data obtained for different parameters were statistically analyzed in the same way as described in the section 3.1.23.

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER IV
RESULTS AND DISCUSSION

4.1 (Experiment 1) Effects of fertilizer, manure and irrigation on nutrient contents in leachate and yield of rice

The results obtained from the Experiment 1: Movement of N, P, K and S in undisturbed soil columns with different levels of irrigation, fertilizers and manure with rice culture are presented and discussed in this chapter.

4.1.1 Effect of different irrigation and fertilizer on N and P leaching during boro rice growing period

The results of N and P leaching during boro rice growing period are mentioned in the Table 4.1.1. to 4.1.3.

4.1.1.1 Effect of different levels of irrigation practices on N and P leaching through soil column during boro rice growing season

The effect of irrigation on leachate N and P concentrations were not significantly influenced except P at 40 DAT.The higher N concentrations were found in the saturated irrigation treatment compared to continuous flooded condition.The highest leachate N concentration (6.44 mg L^{-1}) was obtained at 60 days after transplantation where saturated irrigation was applied (I_2) and lowest leachate N concentration was obtained at I_1 treatment at 40 days after transplantation. The higher N leaching at 60 days after transplantation may be due to higher N application, increasing temperature and microbial activity. The leachate P concentrations were significantly affected by fertilizer treatments and decreased with increasing days after transplantation (DAT).

Table 4.1.1Effect of irrigation on the leachate nitrogen and phosphorus concentration during boro rice growing period

Irrigation	N(ppm)			Available P(ppm)		
	20DAT	40DAT	60DAT	20DAT	40DAT	60DAT
I_1	3.92	2.89	5.49	1.32b	0.332	0.338
I_2	4.29	3.32	6.44	1.64a	0.315	0.303
SE(±)	NS	NS	NS	0.06	NS	NS

I_1 = Traditional irrigation, I_2 = Saturated condition.

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

The leachate P concentration of 20 days after transplantation varied significantly with irrigation treatment. The higher leachate P concentrations were obtained in saturated irrigation (I_2) treatment at 20 days after transplantation. The leachate P concentration decreased with increased days after transplantations. The leachate P concentrations of 40 and 60 days after transplantation were not significantly different with the variations of irrigation. In $I_1$and I_2 treatments, 4-5 times lower levels of P concentrations were obtained in the leachate of 40 and 60 days after transplantation in comparison to the leachate samples of 20 days after transplantation. The leachate P concentration of 20 days after transplantation significantly influenced with the variation of irrigation treatments. The higher levels of leachate P concentrations were found in both irrigation treatments at 20 days after transplantation then decreased with increasing duration. The highest P concentration (1.64 ppm) was found in the leachate of I_2 irrigation treatment at 20 days after transplantation and lowest (0.303 ppm) was found in the leachate ofI_2irrigation treatment at 60 days after transplantation. The leachate P concentration decreased with increasing days may be due to increased fixation with soil colloid. The lower nutrient concentrations in the continuous flooded irrigation due to more diluted N and P in presence of higher amount of water and in soil.

4.1.1.2 Effect of different fertilizer treatments on the leachate N and P concentrations during boro rice growing period

The leachate N and P concentration increased with the application of fertilizer treatments. The leachate N concentrations were not significantly affected with the application of different fertilizer treatments. In all the treatments higher levels of leachate, N were obtained at 60 days after transplantation. The highest leachate N concentration (7.23 ppm) was found in T_4 treatment at 60 days after transplantation and lowest (2.60 ppm) in T_0 treatment at 40 days after transplantation. The higher leachate N concentrations were found in T_1 treatment due to higher solubility of inorganic fertilizers (Table 4.1.2).

The leachate P concentrations of different dates were significantly influenced with the application of different fertilizer treatments. The higher leachate P concentrations were found at 20days after transplantation and decreased with increasing daysand similar levels were found in the leachate samples of 40 and 60 days after transplantation of rice. At 20 days after transplantation, the highest P concentration (1.72 ppm) was obtained in the leachate of T_1 treatment which was statistically similar to all other fertilizer treatments except T_0 treatment. The higher leachate P concentrations were found in the T_4 treatment which was statistically similar with all other treatments except T_0 treatment (Figure4.1).

The soluble P concentration decreased in the leachate due to increasing precipitation with soil colloid with increasing of time. Comparatively higher levels of P were obtained in T_2, T_3 and T_4 (organic + inorganic fertilizer) treatments during at 40 and 60 days after transplantation. Higher levels of leachate P in organic plus inorganic fertilizer treatments during 40 and 60 days after transplantation indicate that slow and continuous release of P from manure may increase the level of P during 40 and 60 days after transplantation.

Table 4.1.2 Effect of fertilizer on the leachate nitrogen concentrations during boro rice growing period

Fertilizer	N(ppm)		
	20 DAT	40 DAT	60 DAT
T_0	2.90	2.60	4.02
T_1	4.20	3.67	7.07
T_2	4.17	3.50	5.13
T_3	3.73	2.80	5.37
T_4	4.53	2.97	7.23
SE(±)	NS	NS	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

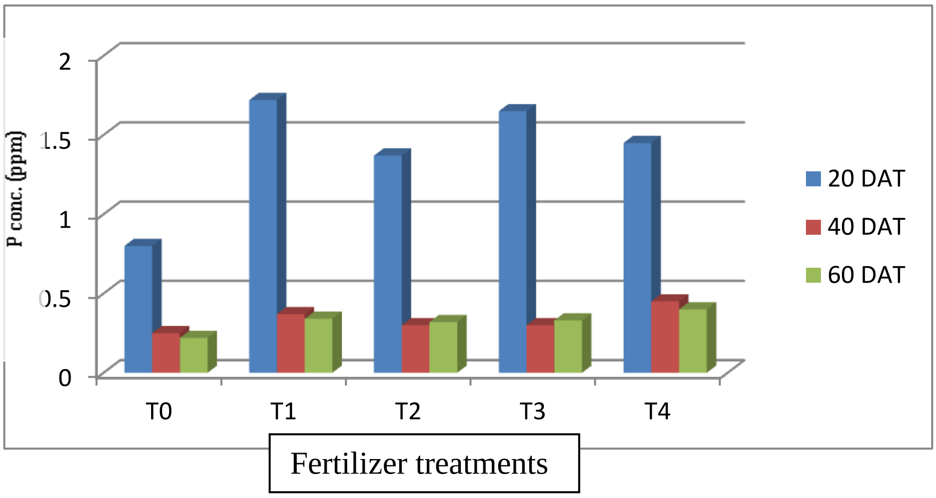


Figure 4.1 Leachate P concentrations during boro rice growing period at 20, 40 and 60 DAT

4.1.1.3 The interaction effects of irrigation and fertilizers on the N and P concentrations during boro rice growing period

The leachate N concentrations at 20 days after transplantation were significantly influenced with theinteraction of irrigation and fertilizers and almost similar leachate N concentrations were found in all the treatment combinations except I_1T_0,I_1T_3 and I_2T_0 treatment combinations. The leachate N levels of 40 and 60 days after transplantationwere not significantly influenced with the interaction of irrigation and fertilizer treatments. The higher levels of leachate N concentrations were found at 60 days after transplantationin comparison to 20 and 40 days after transplantation. The highest leachate N concentration (7.93 ppm) was found in I_2T_4 treatment combination. Higher leachate N concentrations at 60 days after transplantation may be the effect of fertilizer application and increasing temperature and microbial activity.

The P concentrations in the leachate samples of different dates were not significantly affected with the interaction of different fertilizer and irrigation levels. All the treatment combinations gave higher level of leachate P at 20 days after transplantation and then decreased. At 20 days after transplantation the highest leachate P concentrations (2.09 ppm) was found in I_2T_1 treatment combination. At 40 and 60 days after transplantation, the higher levels of leachate P concentrations were observed in I_1T_1, I_1T_3, I_1T_4 and I_2T_4 treatment combinations, than other treatment combinations.

Table 4.1.3 Interaction effect of irrigation and fertilizer on the leachate nitrogen and phosphorus concentration during boro rice growing period

Irrigation and Fertilizer	N(ppm)			P(ppm)		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
I_1T_0	3.13b	2.60	3.03	1.07	0.239	0.266
I_1T_1	4.20ab	3.60	6.67	1.35	0.408	0.396
I_1T_2	4.13ab	3.27	5.13	1.15	0.240	0.306
I_1T_3	3.27b	2.33	6.07	1.41	0.332	0.340
I_1T_4	4.87a	2.67	6.53	1.41	0.441	0.383
I_2T_0	3.14b	2.60	4.00	1.14	0.193	0.173
I_2T_1	4.20ab	3.73	7.47	2.09	0.328	0.280
I_2T_2	4.20ab	3.73	5.13	1.59	0.352	0.331
I_2T_3	4.20ab	3.27	4.67	1.88	0.269	0.325
I_2T_4	4.20ab	3.27	7.93	1.29	0.431	0.404
SE(±)	0.295	NS	NS	NS	NS	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.1.2 Effect of different irrigation and fertilizer on K and S leaching through the soil column during boro rice growing season

The results found on the effect of different irrigation and fertilizer on K and S leaching through the soil column during boro rice growing season are given in the Tables 4.1.4 to 4.1.6.

4.1.2.1 Effect of irrigation on K and S leaching during boro rice growing period

The K concentrations of the leachate samples of 40 and 60 days after transplantation were not significantly influenced by different irrigation treatments. The leachate K and S concentrations at 20 days after transplantation were significantly influenced by different irrigation treatments. The higher K (4.78 ppm) concentration was found in I_2(saturated condition) treatment at 20 days after transplantationand lower (2.42 ppm) in continuous flooded condition(I_1) (Table 4.1.4) in the leachate at 20 days after transplantation of boro rice. No significant variation was observed at 40 and 60 days after transplantation.The different levels of irrigation significantly influenced the concentration of S in the leachate sample of 20 DAT and higher level of S was obtained in I_2 treatment.

Similar level of S were obtain in I_1 and I_2 treatments at 40 days after transplantation. The leachate S concentration increased with increasing days after transplantation.

Table 4.1. 4 Effect of irrigation on the leachate potassium and sulphur concentration during boro rice growing period

Irrigation	K(ppm)			S (ppm)	
	20DAT	40DAT	60DAT	20DAT	40DAT
I_1	2.42b	2.91	1.68	1.37b	2.11
I_2	4.78a	3.15	1.84	2.15a	2.11
SE(±)	0.143	NS	NS	0.14	NS

I_1 = Traditional irrigation, I_2 = Saturated condition.

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.2.2 Effect of fertilizer on K and S leaching during boro rice growing period

The K and S leaching were significantly influenced by different fertilizer treatments. The higher concentrations of K (4.86 ppm) was found in the T_4 treatment (50% NPKSZn+ 3.5 ton poultry manure ha^{-1})which was closely similar to T_1(4.72 ppm)treatment and the lowest K(1.60 ppm) leaching was found in the T_0 (control) treatment (Table 4.1.5). Similarly in the leachate of 40 days after transplantation,the highest leachate K (4.40 ppm) concentration was found from the same T_4 treatment and lowest in control. The leachate K concentration was decreased with increasing days after transplantation. The higher level of K in poultry manure and higher solubility of K in MP may increase the level of K in leachate samples.

The leachate S concentration over the dates and fertilizer treatments varied from 1.21-2.51 ppm. At 40 days after transplantation the leachate S concentration significantly influenced with the fertilizer treatments. The highest leachate S concentration (2.51 ppm) was found in T_1 treatment which was statistically and closely similar to T_4 treatment and the lowest was obtained in T_0 treatment.Similarly higher S concentrations in the leachate of 40 days after transplantation were observed in the T_2.

Table 4.1.5 Effect of fertilizer on the leachate potassium and sulphur concentration during boro rice growing period

Fertilizer	K(ppm)			S(ppm)	
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT
T_0	1.60 c	1.86	1.30 b	1.21	1.73 b
T_1	4.72 a	3.46	2.43 a	1.88	2.51 a
T_2	3.47 b	2.98	1.84 ab	2.15	2.04 ab
T_3	3.36 b	2.46	1.70 b	1.98	1.79 ab
T_4	4.86 a	4.40	1.55 b	1.51	2.50 a
SE(±)	0.23	0.26	0.16	NS	0.19

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.2.3 Interaction effects of irrigation and fertilizer on K and S leaching during boro season

The leachate K and S concentrations in the leachate were positively correlated with grain and straw yields of rice. At 20 days after transplantation, the K leaching was significantly influenced by interaction of irrigation and fertilizer and the range of K leaching varied from 1.46 to 6.20 ppm. The highest leachate K concentration was found in the I_2T_1 (saturated condition plus recommended dose of fertilizer) treatment combination which was closely similar to I_2T_2, I_2T_3, I_2T_4 treatment combinations and the lowest in I_1T_0 treatment combination (Table 4.1.6). The leachate K concentration of 40 and 60 days after transplantationwere not statistically significant with the interaction effect of irrigation and fertilizer. The K concentration decreased with increasing days after transplantation. At 40 days after transplantation, higher levels of K were found in the leachate of I_1T_4 and I_2T_4 treatment combination may be due to continuous release of K from poultry manure. The leachate K level decreased more at 60 days after transplantation and varied over the treatment combinations from 1.21 to 2.83 ppm.

The interaction effect of irrigation and fertilizer were not significantly influenced the leachate S concentration at 20 and 40 days after transplantation. The numerically maximum levels of S containing leachate were observed in most of the treatment conbinations at 40 days after transplantation in comparison to 20 days after transplantation. The leachate S concentration varied 1.14-3.13 ppm over the dates and treatment combinations. The maximum leachate S concentration (3.13 ppm) was obtained in I_2T_2 treatment combination and minimum (1.14 ppm) in I_1T_0 treatment combination.

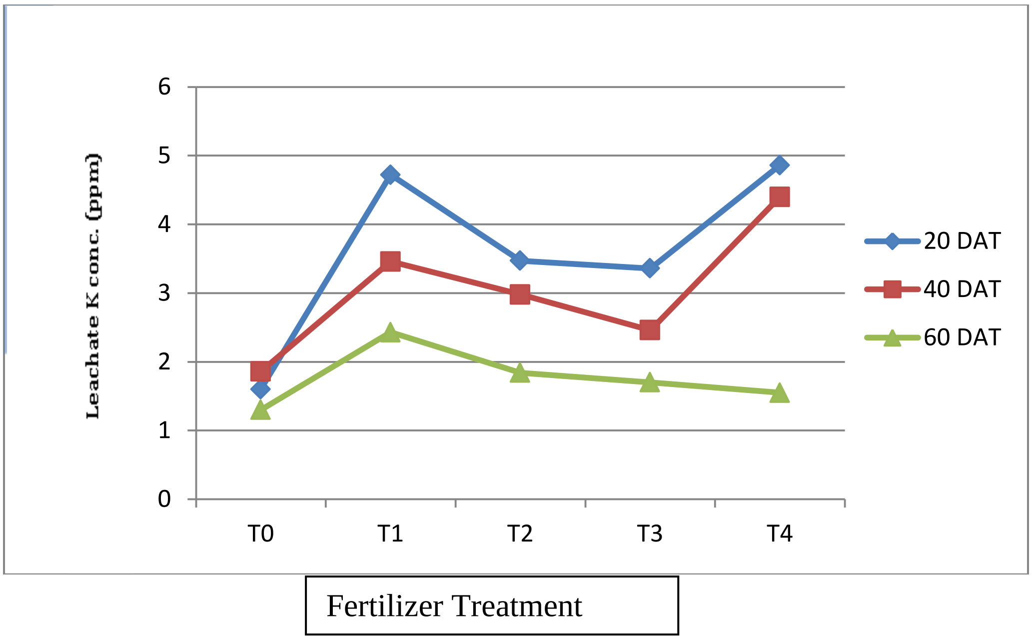


Figure 4.2 Effect of fertilizer on the leachate potassium and sulphur concentration during boro rice growing period

Table 4.1.6 Interaction effect of irrigation and fertilizer on the leachate potassium and sulphur concentration during boro rice growing period

Irrigation and Fertilizer	K(ppm)			S(ppm)	
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT
I_1T_0	1.46d	1.92	1.21	1.14	1.73
I_1T_1	3.24c	2.94	2.02	1.59	2.66
I_1T_2	1.58d	2.63	1.78	1.17	1.79
I_1T_3	1.67d	2.96	2.00	1.67	1.98
I_1T_4	4.19bc	4.11	1.39	1.21	2.41
I_2T_0	1.73d	1.80	1.39	1.37	1.73
I_2T_1	6.20a	3.98	2.83	2.18	2.36
I_2T_2	5.36ab	3.33	1.90	3.13	2.29
I_2T_3	5.06ab	1.95	1.39	2.28	1.60
I_2T_4	5.54a	4.68	1.70	1.81	2.59
SE(±)	0.32	NS	NS	NS	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.1.3 Effect of different irrigation and fertilizer on the yield parameter and yield of boro rice

4.1.3.1 Effect of irrigationon the yield parameters and yield of boro rice

Theplant height, panicle length, filled grains panicle^{-1}, unfilled grain, 1000 grain weight were not significantly affected by irrigation but the grain and straw yields were significantly influenced by irrigation. The higher plant height, filled grains/panicle and 1000grain weight were obtained in the continuous flooded condition in comparison to saturated irrigation.The higher grain (76.03 gcore^{-1}**)** and straw yield (64.75 g core^{-1}) were obtained in the continuous flooded (I_1) irrigation than saturated condition (I_2)(Table 4.1.7).

Table 4.1.7 Effect of irrigation on plant height, panicle length, filled grains, unfilled grains, 1000-grain weight, grain yield and straw yield of boro rice

Irrigation	Plant height (cm)	Panicle length (cm)	Filled grain Panicle^{-1} (no.)	Unfilled grains Panicle^{-1} (no.)	1000 grain weight(g)	Grain weight (g core^{-1})	Straw yield (g core^{-1})
I_I	75.23	22.27	107.9	24.32	19.93	76.03a	64.75a
I_2	74.79	22.37	106.5	22.76	19.51	63.99b	58.85b
SE(±)	NS	NS	NS	NS	NS	1.62	1.98

I_1= Traditional irrigation, I_2 = Saturated condition

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.3.2 Effect of fertilizer on the yield parameters and yield of boro rice

The plant height and panicle length were significantly influenced by fertilizer treatments but filled grains panicle^{-1} and 1000 grain weight were not significantly affected by fertilizer treatments. The highest plant height (78.10 cm) was found in T_2 (50% NPKSZn + 5 ton cowdung ha^{-1}) treatment which was statistically similar to all other treatment except control. The T_4 (50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment gave the tallest panicle length (23.63 cm) and the lowest in control treatment (Table 4.1.8). The grain and straw yields were significantly influenced by fertilizer treatments. The highest grain yield (88.42g core^{-1}) was found in T_1(RDCF) treatment which was closely similar to T_4(88.32 g core^{-1}) treatment and the lowest was obtained from control treatment. Higher level of N, P and K concentrations were found in the leachate of T_1 and T_4 treatments. Similarly, the highest straw yield was found in T_1 treatment which was statistically similar to all other treatments except control. There was a good correlation between leachate N, P and K concentrations and yield of rice.

Table 4.1.8 Effects of fertilizer on plant height, panicle length, filled grains, unfilled grains, 1000-grain weight, grain yield and straw yield of boro rice

Irrigation	Plant height (cm)	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight(g)	Grain yield (g core^{-1})	Straw yield (g core^{-1})
T_0	67.07b	22.40b	89.90	22.29	19.26	26.12c	21.52b
T_1	76.57a	23.48ab	115.1	20.47	19.88	88.42a	76.88a
T_2	78.10a	24.03a	112.8	26.41	19.58	72.62b	71.17a
T_3	75.50a	23.05ab	103.7	23.29	19.91	74.58b	65.83a
T_4	77.83a	23.63a	114.4	25.23	19.99	88.32a	73.58a
SE(±)	1.26	0.303	NS	NS	NS	2.57	3.14

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.3.3 Interaction effects of irrigation and fertilizer on yield parameters and yield of boro rice

The yield parameters and straw yields were not significantly influenced by the interaction effect of fertilizer and irrigation but the grain yields were significantly influenced with the interaction effects of fertilizer and irrigation. The highest grain yield (92.77g core^{-1}) was obtained from I_1T_4 (continuous flooded + 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combination which was statistically comparable to I_1T_1 (continuous flooded + RDCF), I_1T_2 (continuous flooded + 50% NPKSZn+ 5 ton cowdung ha^{-1}), I_1T_3 (continuous flooded + 50% NPKSZn+ 5 ton compost ha^{-1}) and I_2T_4(saturated condition plus 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combinations and the lowest grain yield was found from I_2T_0(saturated condition and fertilizer control) treatment combination(Table 4.1.9). The leachate N, P and K concentrations of different dates were significantly and positively correlated with the grain and straw yield of boro rice.

Table 4.1.9 Effects of irrigation and fertilizer on plant height, panicle length, filled grain, unfilled grain and 1000-grain weight of boro rice

Irrigation and fertilizer	Plant height (cm)	Panicle length (cm)	Filled grain Panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 grain weight (g)
I_1T_0	67.53	22.27	88.5	25.79	19.47
I_1T_1	75.77	23.63	116.2	21.22	19.99
I_1T_2	78.97	24.40	115.2	25.90	19.59
I_1T_3	75.90	22.80	103.9	25.18	20.17
I_1T_4	78.00	23.27	115.6	23.48	20.44
I_2T_0	66.60	22.53	91.3	18.79	19.06
I_2T_1	77.37	23.33	114.0	19.72	19.78
I_2T_2	77.23	23.67	110.4	26.92	19.56
I_2T_3	75.10	23.30	103.5	21.40	19.64
I_2T_4	77.67	24.00	113.1	26.97	19.53
SE (±)	NS	NS	NS	NS	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

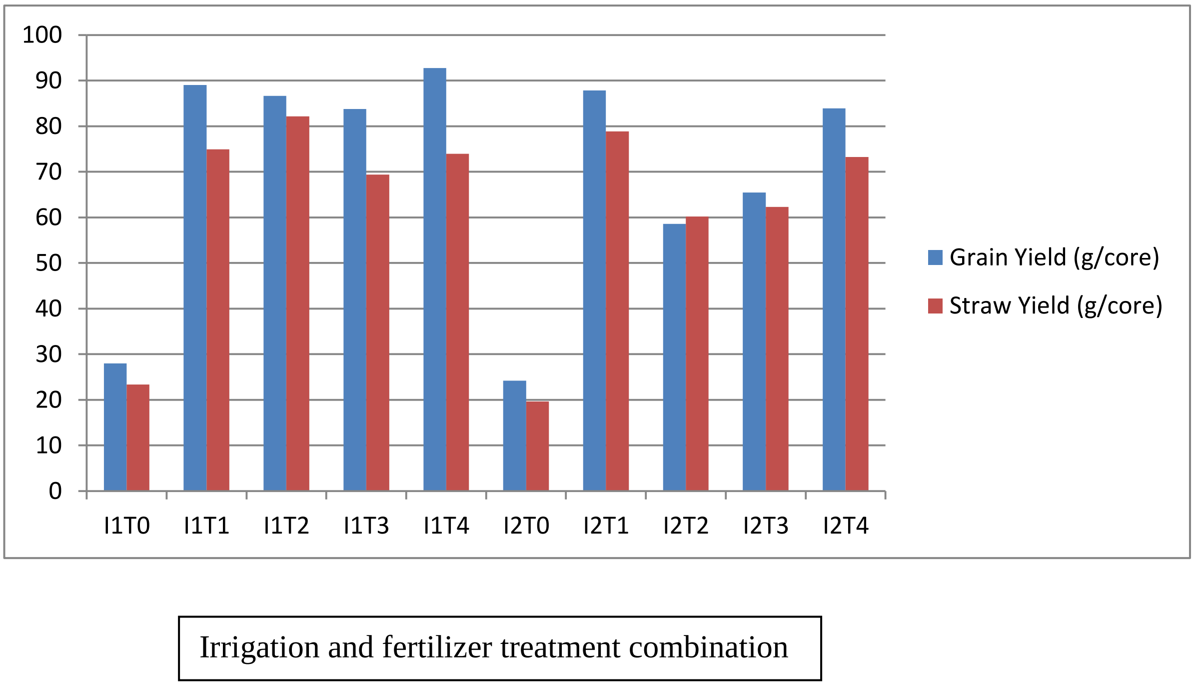


Figure 4.3 Interaction effects of irrigation and fertilizer on the yield of boro rice

4.1.4 Effect of irrigation and Fertilizer on NPK leaching during T. aman rice growing period

The experimental results on effect of irrigation and fertilizer on leaching through the soil column during T. aman rice growing season are given in the Tables 4.1.10 to 4.1.12.

4.1.4.1 Effect of irrigation on NPK leaching during T. aman rice growing period

The results showed that the N, P and K leaching at 20 days after transplantation were significantly influenced by irrigation treatments. The leachate N concentration increased at 40 days after transplantation in comparison to 20 days after transplantation and opposite trend was observed for P and K. Higher concentrationof P in the leachate of 20days after transplantation was found in the I_1 (continuous flooded) treatment and lower concentration the samples of saturated soil condition. The concentrations of K in the leachate were significantly influenced by irrigation treatments. The higher concentrations of leachate K were found in the saturated condition (I_2) than the leachate samples of continuous flooded irrigation.The leached P and K concentrations decreased at 40 days after transplantation and very low levels of P were found in the leachate of 40 days after transplantation may be due to rapid precipitation with the soil colloids. The P and K concentrations in the leachate samples decreased with increasing dates after transplantation may be due to fixation, plant uptake and leaching.

Table 4.1.10 Effect of irrigation on the leachate nitrogen, phosphorus and sulphur concentrations during T. aman rice growing period

Irrigation	N (ppm)		P (ppm)		K (ppm)	
	20DAT	40DAT	20DAT	40DAT	20DAT	40DAT
I_1	2.91a	4.04	2.42a	0.023	1.02b	0.63b
I_2	2.69b	3.90	1.84b	0.017	1.34a	1.11a
SE(±)	0.14	NS	0.08	NS	0.07	0.10

I_1 = Traditional irrigation, I_2 = Saturated condition

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.4.2 Effect of Fertilizer, Manure on NPK leaching during T. aman rice growing period

The leachate N, P and K concentrations were significantly influenced by fertilizer treatments. The leachate N concentrations increased at 40 days after transplantation in all the fertilizer treatments in comparison to the leachate samples of 20 days after transplantation may be due to application of N and increasing temperature and mineralization. The highest N concentration in the leachate (4.27 ppm) was found in the T_1(Recommended dose of fertilizer) treatment at20days after transplantation and the lowest in the control treatment. (Table 4.1.11). At 40 days after transplantation, the highest N concentration (5.60 ppm) was found in T_1 treatment which was statistically similar to the T_2(50% NPKSZn+ 5 ton cowdung ha^{-1}) and T_3 (50% NPKSZn+ 5 ton compost ha^{-1}) treatments. The P leaching decreased with increasing days after transplantation. At 20days after transplantation, the highest P concentration of 3.17 ppm was found in the T_2 treatment and the same treatment contains only 0.02 ppm P at 40 days after transplantation and similar leachate P concentrations were found in all other fertilizer treatments. The leachate K concentration moderately decreased with increasing days after transplantation. At 20days after transplantation the highest concentration of leachate K (1.43 ppm) was found in T_3 (50% NPKSZn+ 5 ton compost ha^{-1}) treatment which was statistically similar to all other treatments except control (T_0). At 40days after transplantation, the highest K concentration (1.21ppm) was found in the T_4 treatment and higher grain yield was recorded from this treatment. The higher levels of K released in the soil solution at 40 DAT where inorganic fertilizer plus poultry manure were applied.

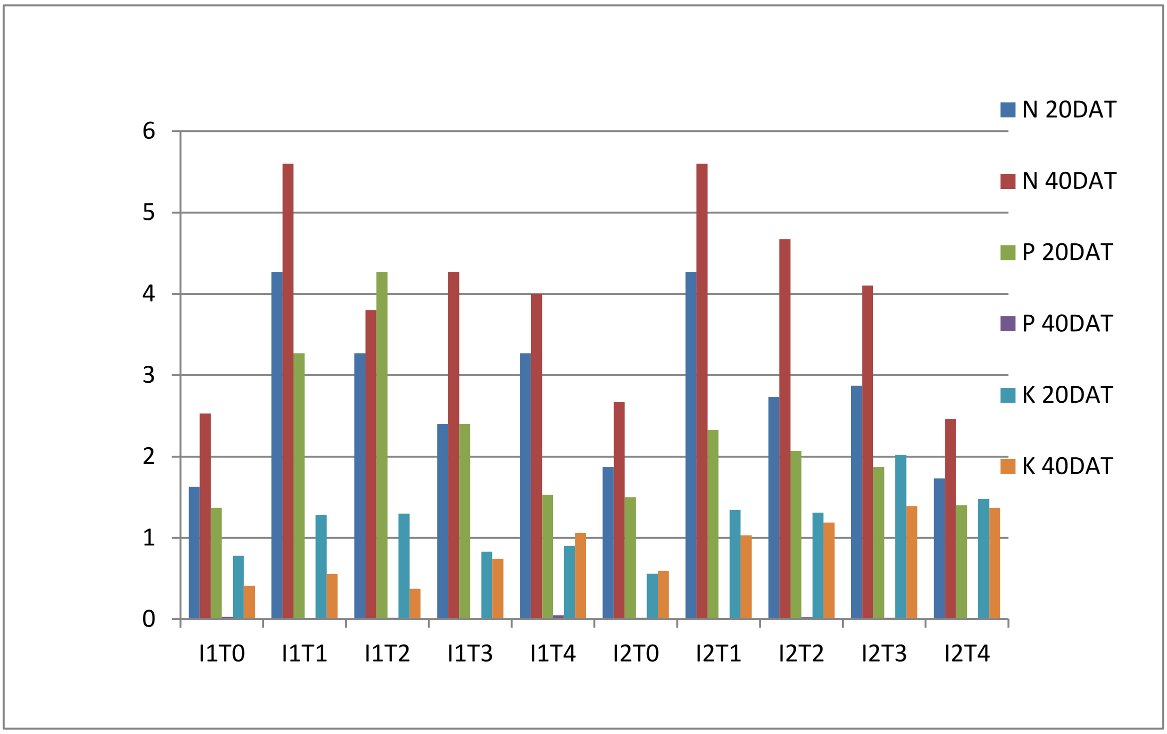
Table 4.1.11 Effect of fertilizer on the leachate nitrogen, phosphorus and potassium concentration during T. aman rice growing period

Fertilizer treatment	N(ppm)		P(ppm)		K(ppm)	
	20DAT	40DAT	20DAT	40DAT	20DAT	40DAT
T_0	2.10c	2.60b	1.60b	0.022ab	0.67b	0.50b
T_1	4.27a	5.60a	2.80a	0.013c	1.31a	0.80ab
T_2	3.00b	4.23ab	3.17a	0.020bc	1.30a	0.78ab
T_3	2.13bc	4.18ab	1.63b	0.013c	1.43a	0.06ab
T_4	2.50bc	3.23b	1.45b	0.030a	1.19a	1.21a
SE(±)	0.22	0.42	0.12	0.004	0.11	0.16

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.4.3 Interaction effects of irrigation and fertilizers on NPK leaching on T. aman rice

The yields were correlated with the leachate N, P and K concentrations. The N, P and K concentrations were significantly influenced by the interaction effects of irrigation and fertilizer. At 20 days after transplantation, the leachate N ranged from 1.63- 4.27 ppm, P ranged from 1.37 to 4.27 ppm and leachate K ranged from 0.56-2.02 ppm. At 20 days after transplantation the highest leachate N concentration was obtained from I_1T_1 and I_2T_1 treatment combinations and the highest P concentration was observed in I_1T_2(continuous flooded + 50% NPKSZn+ 5 ton cowdung ha^{-1}) treatment combinations. In the sample of 20 days after transplantation, the highest K concentration (2.02 ppm) was found from the I_2T_3 treatment combination where 50% NPKSZn plus 5 ton compost ha^{-1} and saturated irrigation treatment were applied (Figure 4.4) which was statistically similar to I_2T_4 treatment combination. At 40 days after transplantation, the leachate P concentration highly decreased and the highest concentration of 0.047 ppm was found in I_1T_4 (continuous flooded + 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combination. At 40days after transplantation, the leachate K concentration decreased slightly in inorganic plus organic fertilizer applied treatment and the highest K concentration of 1.39 ppm was obtained from I_2T_3 treatment combination. The increasing level of leachate N at 40 days after transplantation may be due to the effects of N application and increasing mineralization due to increasing temperature and microbial activity in soil. Higher levels of leachate K concentrations were observed in the treatment combinations where inorganic plus organic fertilizers were applied.



Irrigation and fertilizer treatment combinations in T. aman growing period

Figure 4.4 Leachate nutrient (NPK) concentration due to interaction effect of irrigation and fertilizer treatments

4.1.5 Effect of irrigation and fertilizer on the yield parameters and yield of T. aman rice

The results found on the yield and growth parameters are given in the Tables 4.1.13 to 4.1.15.

4.1.5.1 Effect of irrigationon yield parameters and yield of T. aman rice

The plant height, panicle length and thousand grain weight were not significantly influenced by irrigation treatments but higher plant height and panicle lengths were found in the continuous flooded irrigation treatment. The filled grains panicle^{-1}, grain yield and straw yields were significantly influenced by irrigation treatments. The higher number of filled grains panicle^{-1} was found in continuous flooded irrigation treatment. The higher grain and straw yield were obtained from continuous flooded irrigation

Table 4.1.12 Effect of irrigation on plant height, panicle length, filled grain, unfilled grain, 1000-grain weight, grain and straw yield of T. aman rice

Irrigation	Plant height(cm)	Panicle length(cm)	Filled grains/panicle (No.)	1000 grain weight(g)	Grain yield (gcore^{-1})	Straw yield (gcore^{-1})
I_I	85.07	20.45	145.6a	17.53	71.07a	75.71a
I_2	81.67	19.96	132.5b	17.40	57.15b	67.31b
SE(±)	NS	NS	2.43	NS	1.57	2.08

I_1= Traditional irrigation, I_2= saturated condition

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.5.2 Effect of fertilizeron yield parameter and yield of T. aman rice

The plant height, panicle lengths, filled grains panicle^{-1}, grain and straw yields were significantly influenced by fertilizer treatments. The T_2 treatment gave the highest plant height and panicle length which was statistically similar to all other treatments except control. The highest number of filled grains/panicle was noticed in the T_3 treatment which was statistically comparable to T_2 treatment and the lowest number was found in T_0 treatment. The highest grain yield of 83.65g core^{-1} was obtained from T_1 treatment and the next highest grain yield was found in T_4 treatment and the lowest from control treatment. Similarly, the highest straw yield was found in T_1 treatment which was statistically similar to T_4 treatment (Table 4.1.13). Among the organic plus inorganic fertilizer treatments, poultry manure applied treatment showed better performance.

Table 4.1.13 Effect of fertilizer on plant height, panicle length, filled grains, unfilled grains, 1000-grain weight, grain yield and straw yield of T. aman rice

Fertilizer	Plant height (cm)	Panicle length(cm)	Filled grain $panicle^{-1}$	1000-grain weight(g)	Grain yield ($gcore^{-1}$)	Straw yield ($gcore^{-1}$)
T_0	73.82b	18.82b	119.1c	17.00	22.85c	28.57c
T_1	86.62a	20.70a	136.3b	17.83	83.65a	94.85a
T_2	86.38a	20.92a	149.7ab	17.50	72.10b	74.43b
T_3	85.75a	20.62a	153.8a	17.50	69.65b	76.22b
T_4	84.27a	19.98a	136.7b	17.50	72.32b	83.48ab
SE(±)	2.37	0.29	3.84	NS	2.48	3.29

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.5.3 Interaction effects of irrigation and fertilizers on the yield parameter and yield of T. aman rice

The yield parameter and yields were not significantly affected by the interaction of irrigation and fertilizer treatments. The higher plant height, panicle length and 1000 grain weight were found in the I_1T_1 treatment combination and lower in I_1T_0 and I_2T_0treatment combinations. The highest number of filled grains/panicle was obtained in the I_1T_2 treatment combination and lowest in I_2T_0 treatment combination. The grain yield over the treatments varied from 17.73 to 91.90 g $core^{-1}$ and the highest grain yield was found in I_1T_1(continuous flooded condition + RDCF) treatment combination and the lowest in I_2T_0 treatment combination(Table 4.1.14). The straw yield over the treatment combination varied from 23.27 to 96.80 g $core^{-1}$ and the highest straw yield was obtained in the I_1T_1(Continuous flooded irrigation + Recommended dose of chemical fertilizer) treatment combination and the lowest in I_2T_0(saturated condition plus fertilizer control) treatment combination.

Table 4.1.14 Effects of irrigation and fertilizer on plant height, panicle length, filled grains, unfilled grains, 1000-grain weight, grain yield and straw yield of T. aman rice

Irrigation and Fertilizer	Plant height (cm)	Panicle length(cm)	Filled grain Panicle^{-1} (no.)	1000 grain weight (g)	Grain yield (gcore^{-1})	Straw yield (gcore^{-1})
I_1T_0	75.60	19.27	123.4	17.00	27.97	33.87
I_1T_1	89.97	21.23	144.8	18.00	91.90	96.80
I_1T_2	88.63	20.97	158.2	17.67	77.53	78.70
I_1T_3	86.03	20.70	153.2	17.33	79.47	81.93
I_1T_4	85.10	20.10	148.6	17.67	78.50	87.27
I_2T_0	72.03	18.37	114.7	17.00	17.73	23.27
I_2T_1	83.27	20.17	127.7	17.67	75.40	92.90
I_2T_2	84.13	20.87	141.2	17.33	66.67	70.17
I_2T_3	85.47	20.53	154.3	17.67	59.83	70.50
I_2T_4	83.43	19.87	124.8	17.33	66.13	79.70
SE(±)	NS	NS	NS	NS	NS	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.6 Effect of different fertilizer and manure on the change chemical properties of soils

After boro and T. aman rice experiment, post harvest soil samples were collected and analysed**.** The results found on the soil chemical properties are given in the Tables 4.1.15 to 4.1.17.

The effect irrigation and fertilizer singly and in combination as per soil are given below in the tables 4.1.15, 4.1.16 and 4.1.17.

4.1.6.1 Effect of irrigationon the change chemical properties of soils

The irrigation treatments did not significantly affect the level of organic matter, available P and K concentrations of post-harvest soil but the soil pH was significantly increased in the soils where saturated irrigation was applied. The pH value of 6.9 was found in the post experiment soils of I_2 (saturated irrigation) treatment and lower (6.6) in the soil samples of I_1 (continuous flooded) treatment (Table 4.1.15).

Table 4.1.15 Effect of irrigation on the chemical properties of post experiment soil

Irrigation	Soil organic matter (%)	Soil pH	Available P(ppm)	Available K(ppm)
I_I	1.34	6.6b	16.13	22.55
I_2	1.37	6.9a	16.71	18.61
SE(±)	NS	0.03	NS	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT, NS- Non significant.

4.1.6.2 Effect of Fertilizer on the change in chemical properties of soils

The level of organic matter, soil pH and available P were significantly influenced by different fertilizer treatments. The level of organic matter ranged from 1.15 to 1.46% and the highest level of organic matter was obtained in T_4 (50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment which was statistically similar to all other treatments except control (Table 4.1.17). The post-harvest soil pH ranged from 6.4 to 7.0 and the highest pH was obtained in T_4 treatment where 50% NPKSZn+ 3.5 ton poultry manure ha^{-1} were used and the lowest in control treatment. The increased pH of post-experiment soils were also found in the T_2, T_3 and T_4 treatments (Table 4.1.16). The higher pH increase was observed in the post experiment soils of poultry manure applied treatment. The level of P and K concentration were increased more where fertilizer plus manure applied. The available P of post-harvest soils over the treatments ranged from 13.25 to 20.66 ppm and the highest P concentration of 20.66 ppm was found in the T_4 treatment where 50% NPKSZn+ 3.5 ton poultry manure ha^{-1} were used which was statistically similar to T_2 (50% NPKSZn+ 5 ton cowdung ha^{-1}) and T_3 (50% NPKSZn+ 5 ton compost ha^{-1}) treatments where fertilizer and manures were used in combination. The level P and K increased for the residual effect of applied manure during rice cultivation.

Table 4.1.16 Effect of fertilizer on the post experiment soil properties

Fertilizer treatments	Soil pH	Organic Matter (%)	Avail. P(ppm)	Avail. K (ppm)
T_0	6.4c	1.15b	14.17c	17.03
T_1	6.7b	1.35a	13.25c	22.31
T_2	6.8b	1.39a	15.69bc	21.15
T_3	6.7b	1.42a	18.32ab	21.92
T_4	7.0a	1.46a	20.66a	20.51
SE(±)	0.05	0.05	0.94	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.6.3 Interaction ffects of irrigation and fertilizer on the change in chemical properties of soils

The level of organic matter, soil pH and available P concentrations were not significantly affected by the interaction effects of fertilizer and irrigation treatments. The level of organic matter ranged from 1.10 to 1.48%. The highest level of OM was found in the I_1T_4 (continuous flooded plus 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combination and the lowest in I_1T_0 (continuous flooded irrigation and fertilizer control) treatment combination (Table 4.1.17). The soil pH of post harvest soil increased more in saturated irrigation in combination with different fertilizer treatments. The level of pH over the treatment combinations varied from 6.3 to 7.2. The highest pH was found in the I_2T_4 (saturated irrigation + 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combination and the lowest in I_1T_0 (continuous flooded irrigation and fertilizer control) treatment combination. The higher pH values in different fertilizer treatment in combination with alternative wetting and drying may be due to lower leaching of applied and soil basic cations in comparison to continuous flooded irrigation.The highest available P concentration in post-experiment soil (23.28 ppm) was recorded in I_2T_4(saturated irrigation + 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combination and lowest in I_2T_0(saturated irrigation + without fertilizer application) treatment combination. The post-harvest soil available K concentrations were significantly influenced by interaction effects of irrigation and fertilizer treatments. The post-experiment soil available K concentration varied from 11.74 ppm to 28.64 ppm. The higher concentrations of available K were found in the post-experiment soils where fertilizer treatments were applied in combination with continuous flooded irrigation. The highest concentration of available K (28.46 ppm) was found in the I_1T_3 (continuous flooded irrigation + 50% NPKSZn+ 5 ton compost ha^{-1}) treatment combination and the lowest K concentration of 11.74 ppm was obtained in I_1T_0(continuous flooded irrigation and fertilizer control) treatment combination. The water hyacinth composed was applied in I_1T_3 and I_2T_3 treatment combination which increased the post harvest soil level of K.

Table 4.1.17 Interaction effects of irrigation and fertilizer on the post experiment soil properties

Irrigation and fertilizer	Soil pH	Organic Matter (%)	Available P(ppm)	Available K(ppm)
I_1T_0	6.3	1.10	14.25	11.74b
I_1T_1	6.6	1.31	14.97	25.64ab
I_1T_2	6.7	1.38	15.72	21.28ab
I_1T_3	6.5	1.44	18.67	28.46a
I_1T_4	6.9	1.48	18.03	25.64ab
I_2T_0	6.6	1.20	14.08	22.31ab
I_2T_1	6.9	1.38	12.53	18.97ab
I_2T_2	6.8	1.40	15.67	21.02ab
I_2T_3	6.9	1.41	17.97	18.38ab
I_2T_4	7.2	1.44	23.28	18.38ab
SE(±)	NS	NS	NS	3.73

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.7 General Discussion

The continuous flooded irrigation in combination with different fertilizer treatments increased the level of post harvest soil K may be due to more release of K from clay colloids. Nutrient leaching were studied by net house experiment. The leachate nutrient availability and leaching varied with irrigation, fertilizer treatments and time of sample collection. Similar levels of leachate N and S concentrations were found in the leachate samples of different dates but the P and K concentration decreased with increasing time. Higher levels of leachate N, K and S concentrations were found in the 50% inorganic fertilizer plus 3.5 ton poultry manure ha^{-1} and higher rice yields were obtained in this treatment in comparison to other organic plus inorganic fertilizer treatment. Higher concentrations of leachate P and K were found in the organic plus inorganic fertilizer treatments and recommended fertilizer applied treatment. The higher levels of leachate N concentration were obtained in I_1T_1, I_2T_1, I_1T_4 and I_2T_4 treatment combination and higher boro rice yields were found in the same treatment combinations. There was a significant and positive correlation between leachate nutrient and rice yields. Application of poultry manure increased the soil pH and available P and higher increase of OM level was observed in the T_4 (50% inorganic fertilizer plus 3.5 ton poultry manure ha^{-1}) treatment in comparison to other organic plus inorganic treatments T_2 and T_3. Phosphorus leaching decreased with increasing days from transplantation but N and S leaching were in similar trend during the rice growing period. Higher leaching of P and K were observed in T_1 (recommended dose of inorganic fertilizer) and T_4 treatments where higher rice yields were obtained. The leachate nutrient concentrations were significantly correlated with the yields of rice. Higher rice yields were found in continuous flooded irrigation than saturated irrigation. Application of poultry manure increased the pH of post experiment soil. Application of organic plus inorganic fertilizer increased the level of organic matter, P and K availability of post experiment soils.The continuous flooded irrigation in combination with different fertilizer treatments increased the level of post harvest soil K may be due to more release of K from clay colloids.

Figure 4.5 Leachate collection system with boro rice culture-set up

4.2 Integrated use of organic and inorganic fertilizer on nutrient in pore water, yield contributing character and yield of rice under traditional and saturated irrigation condition

4.2.1 Effect of irrigation and fertilizer on the yield parameters and yield of boro rice

4.2.1.1 Effect of irrigation on the growth and yield of boro rice

The number of effective tillers hill^{-1}, non-effective tillers hill^{-1}, plant height, filled grains panicle^{-1}, grain and straw yields were not significantly affected by irrigation.The higher number of effective tillers/hill was found in continuous flooded condition than saturated one but the higher number of non effective tiller and number of filled grains/panicle were found in saturated condition than continuousflooded one. The higher panicle length was found to be higher in continuous flooded condition than saturated condition.The higher grain (7.50 t ha^{-1})

and straw yields (7.30 t ha^{-1}) were obtained in continuous flooded irrigation in comparison to saturated irrigation (Grain yield: 7.25 t ha^{-1}, Straw yield: 7.09 t ha^{-1}). The grain and straw yields were not significantly influenced by irrigation treatment.

Table 4.2.1 Effect of irrigation on the yield parameters and yield of boro rice BRRI dhan29

Irrigation treatments	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$	Plant height (cm)	Panicle length (cm)	Number of filled grains $panicle^{-1}$	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_1	14.81	0.54	75.21	22.15	92.41	7.30	7.50
I_2	14.69	0.58	73.29	21.02	92.95	7.09	7.25
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS= Non significant

I_1 = Continuous flooded, I_2 = Saturated condition

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.2.1.2 Effect of fertilizer on the yield parameters and yield of boro rice

Among the different fertilizer treatments, T_6 (50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment showed the highest number of effective tillers/hill (15.7) which was statistically similar to T_7, T_5, T_3,T_2 and T_1treatments. The T_4 (70% NPKSZn + 3 ton cowdung ha^{-1}) showed the highest plant height (77.2 cm), which was statistically similar to all other treatment except T_5 and control. The highest number of filled grains/panicle (103.5) was found in T_6 treatment which was statistically and closely similar to T_7, T_5, T_2 and T_3 treatments. Similarly, the highest panicle length was obtained in T_7 treatment and the control (T_0) treatment gave the lowest number of effective tillers/hill, plant height, panicle length and filled grains $panicle^{-1}$.

The application of fertilizers and manure had a positive and significant effect on the grain and straw yield of boro rice (Table 4.2.2). Among the different doses of fertilizers, T_5 (70% NPKSZn + 3 ton compost ha^{-1}) showed the highest grain yield (7.78 t ha^{-1}) which was closely similar to T_4, T_6 and T_7 treatments and the lowest grain yield (5.39 t ha^{-1}) was observed with T_0 (control) treatment. Similarly, the highest straw yield (7.90 t ha^{-1}) was obtained in T_6 (50%

NPKS + 3.5 ton poultry manure ha^{-1}) treatment which was closely similar to T_2, T_5, and T_7 treatments and the lowest straw yield was obtained in T_0 treatment.

Table 4.2.2 Effect of fertilizer and manure on the yield parameter and yield of boro rice BRRI dhan29

Treatments	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Plant height (cm)	Panicle length (cm)	Number of filled grain panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_0	12.1c	0.97 a	68.20 c	20.76	74.1c	5.39 b	5.81 b
T_1	15.1ab	0.93 a	76.03ab	21.17	90.3 ab	7.04 a	7.31 a
T_2	15.9a	0.27 b	74.34ab	21.59	98.7 ab	7.27 a	7.59 a
T_3	14.6ab	0.37 b	77.18a	21.98	95.0 ab	7.22 a	7.47 a
T_4	14.1b	0.37 b	72.45b	21.23	86.5 bc	7.64 a	7.53 a
T_5	14.9ab	0.33 b	74.14ab	21.49	91.5 ab	7.78 a	7.68 a
T_6	15.7a	0.70 ab	75.93ab	22.01	103.5 a	7.51 a	7.90 a
T_7	15.6a	0.57 ab	75.78ab	22.51	102.2 a	7.75 a	7.73 a
SE (±)	**0.41**	**0.13**	**1.19**	**NS**	**4.07**	**0.22**	**0.21**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.2.1.3 Interaction effects of irrigation and fertilizer on the growth and yield of boro rice

The number of effective tillers/hill and plant height were significantly influenced by combined effects of irrigation and fertilizer. The highest number of effective tillers/hill was found in I_1T_1 (50% inorganic + 5 ton cowdung ha^{-1}) treatment combination which was closely similar to I_1T_3, I_1T_6, I_1T_7, I_2T_1, I_2T_6 and I_2T_7 treatment combinations. The highest plant height (80.7 cm) was recorded in I_1T_3 treatment combination which was closely similar to I_1T_6, I_2T_1 and I_2T_7 treatment combination. The combined effect of different doses of fertilizer and irrigation on the grain yield of boro rice was not significantly different. The highest grain yield of boro rice (7.79 t ha^{-1}) was recorded with the treatment combinations I_2T_7 (saturated condition + 70% inorganic fertilizer and 2.1 ton PM/ha) which was closely similar to I_1T_2 (7.72 t ha^{-1}), I_1T_4 (7.76 t ha^{-1}), I_1T_5 (7.79 t ha^{-1}), I_1T_7 (7.71 t ha^{-1}), I_2T_5(7.77 t ha^{-1}) and I_2T_6 (7.78 t ha^{-1}) treatment combinations and the lowest grain yield (4.97 t ha^{-1}) was found in I_2T_0 (saturated condition + control treatment) treatment combination. The straw yield was not significantly influenced with the interaction of irrigation and fertilizer. The highest straw yield of rice (7.96 t ha^{-1}) was recorded with the treatment combination I_1T_5 (continuous flooded + 50% NPKSZn + 3.5 ton compost ha^{-1}) which was similar to I_1T_5, I_1T_7, I_2T_6 and I_2T_7 treatment combinations.

Table 4.2.3 Interaction effect of irrigation and fertilizer on the yield parameter and yield of boro rice

Treatments	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Plant height (cm)	Panicle length (cm)	Number of filled grain panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_1T_0	11.9f	0.87	70.2de	20.7	69.8	5.8	6.2
I_1T_1	13.9cde	1.13	75.4abcd	20.9	81.7	6.9	7.3
I_1T_2	16.3a	0.33	76.0abcd	22.2	96.4	7.7	7.7
I_1T_3	15.9abc	0.20	80.7a	23.0	96.3	7.4	7.9
I_1T_4	14.2bcde	0.33	73.7bcd	22.4	90.9	7.8	7.3
I_1T_5	14.3abcde	0.13	73.2bcd	21.7	88.6	7.8	7.9
I_1T_6	16.1ab	0.73	78.6ab	23.2	108.1	7.4	8.0
I_1T_7	15.9abc	0.60	73.9bcd	23.3	107.4	7.7	7.7
I_2T_0	12.3ef	1.06	66.2e	20.9	78.3	5.0	5.4
I_2T_1	16.2ab	0.73	76.7abc	21.5	98.9	7.2	7.3
I_2T_2	15.5abc	0.20	72.7bcd	21.0	100.9	6.8	7.4
I_2T_3	13.4def	0.53	73.7bcd	20.9	93.7	7.1	7.0
I_2T_4	13.9cde	0.40	71.2cde	20.1	82.0	7.5	7.7
I_2T_5	15.6abc	0.53	75.0abcd	21.3	94.4	7.8	7.5
I_2T_6	15.3abcd	0.67	73.3bcd	20.9	98.8	7.6	7.8
I_2T_7	15.3abcd	0.53	77.7ab	21.8	96.8	7.8	7.8
SE (±)	**1.9**	**68**	**24.0**	**NS**	**NS**	**4.7**	**NS**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

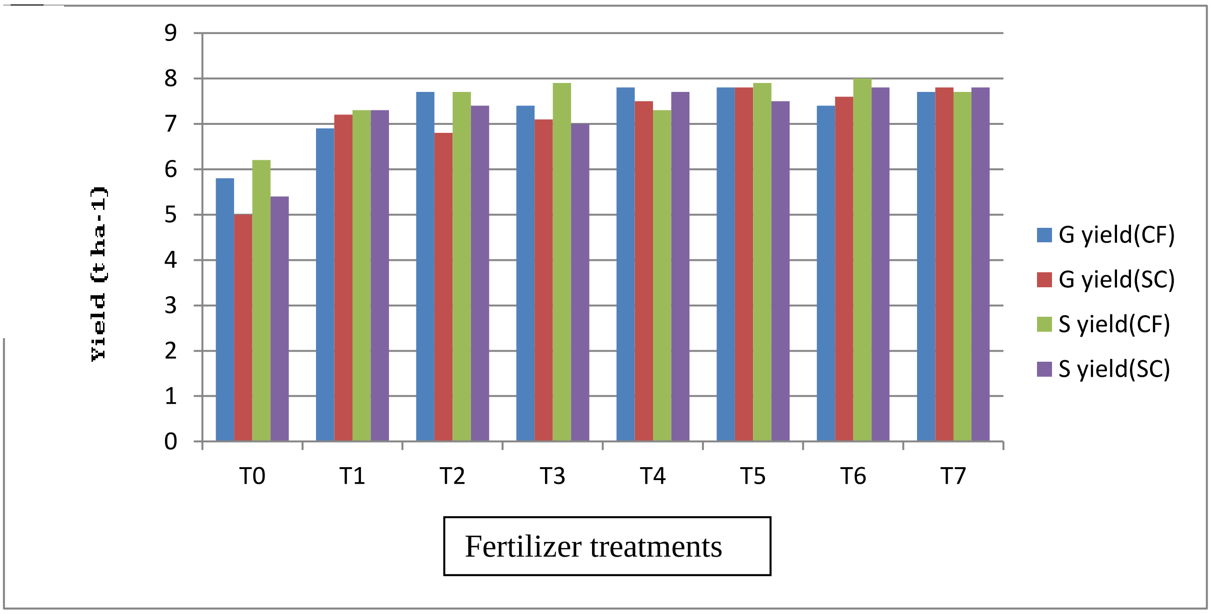


Figure 4.6 Effect of fertilizer and manure on the yield of boro rice BRRI dhan29

4.2.2 Effect of irrigation and fertilizer on N, P and K concentration in the pore Water during tillering stage of boro rice growing period

4.2.2.1 Effects of irrigation, fertilizer and manure on the pore-water N, P and K concentrations in the rice root zone area (outside the core) during boro rice growing period

The pore-water NPK concentrations at tillering stage of rice were not significantly influenced by irrigation treatments. The pore-water N, Pand K concentrations were influenced bydifferent fertilizer treatments. Similar N and P concentrations were found in the I_1 (continuous flooded condition) and I_2 (saturated condition) treatments.

Almost similar N concentrations were found in the pore-water samples of 20 and 40 days after transplantation. The pore-water N concentrations significantly increased in the treatments where fertilizer and manure were applied. Almost similar N concentrations were found in all the treatments except control. Among the fertilizer treatments, the N concentration at 20 days after transplantation varied from 11.80 ppm in T_0 treatment to 17.53 ppm in T_2(50% NPKSZn + 5 ton cowdung ha^{-1}) treatment. At 40 days after transplantation the highest level of available N (15.57 ppm) concentration was obtained from T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure ha^{-1} was used which was statistically similar to all other treatmentsexcept T_0.The pore water N concentration decreased more in the inorganic fertilizer treatment (T_1) with increasing time and almost similar and higher pore water N levels were found in the T_7 treatment. There was a positive correlation between pore water N and rice yield. The presence of higher levels of pore water P in the root zone area of T_5 and T_7 indicated positive impact of poultry manure application and higher yields were obtained in the T_5 and T_7 treatments. The pore-water P and K concentration decreased with increasing days after transplantation. At 20, 40 and 60 days after transplantation, the higher pore water P concentrations were found in the treatment T_7 which was statistically similar to T_5 and T_6 treatments. At 20 days after transplantation, the highest K concentration (11.34 ppm) was found in the T_4 treatment which was closely similar to T_2, T_5, T_6 and T_7 treatments, where inorganic plus organic fertilizers were used. Pore-water K concentration decreased with increasing days after transplantation but higher K concentrations were found in the organic plus inorganic treatments. At 40 days after transplantation the highest K concentration was observed in T_6 treatment which was statistically comparable to T_1, T_3, T_4, T_5 and T_7 treatment.At 60 days after transplantation the highest K concentration was observed in T_4treatment which was statistically similar to $T_{3,}$ $T_6$and T_7 treatments. Treatment

T_2 and T_5 showed almost similar results of pore water K concentration at 60 days after transplantation.

Table 4.2.4 Effect of fertilizer and manure on the pore-water N,P and K concentrations of root zone area (outside the core) at 20, 40 and 60 DAT

Treatments	Pore-water N conc.		Pore-water P conc.			Pore-water K conc.		
	20 DAT	40 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
T_0	11.80c	9.23b	0.54d	0.388b	0.165d	3.89c	1.68d	1.67d
T_1	16.90ab	13.77a	1.21b	0.520ab	0.353bc	8.14ab	3.11bcd	2.25bcd
T_2	17.53a	13.53a	0.81cd	0.540ab	0.372abc	8.78ab	2.83cd	2.08cd
T_3	14.37b	12.83a	0.86bcd	0.505ab	0.397abc	7.55b	3.28abc	2.67abc
T_4	16.1ab	14.23a	1.22b	0.540ab	0.325bc	11.34a	4.56ab	3.42a
T_5	16.57ab	14.77a	1.11bc	0.585a	0.272cd	9.22ab	3.72abc	2.17bcd
T_6	15.03ab	13.60a	1.15bc	0.602a	0.447ab	8.78ab	4.78a	2.92abc
T_7	16.60ab	15.57a	1.69a	0.608a	0.508a	8.67ab	3.50abc	3.0ab
SE (±)	0.73	0.91	0.11	0.42	0.04	0.89	0.42	0.25

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.2.2.2 Interaction effects of irrigation and fertilizer on the pore-water N and P concentration during tillering stage of boro rice

The combined effects of different levels of fertilizer and irrigation on the pore-water N, P and K concentrations were significantly different in the samples of different dates of tillering stage (Table 4.2.3). The almost similar pore-water N concentrations were found in the samples of saturated and continuous flooded condition. At 20 days after transplantation, the highest concentration of 19.20 ppm N was found in I_1T_2 (Continuous flooded condition + 50% NPKSZn + 5 ton cowdung ha^{-1}) treatment combination which was statistically similar to I_2T_4,I_2T_5, I_2T_6, I_2T_7treatment combinations. At 40 days after transplantation, the pore water N concentration varied 9.20 ppm in I_2T_0 to 17.13 ppm in I_1T_7 treatment combination. The pore water P concentrations varied from 0.53- 1.84 ppm at 20 days after transplantation, 0.34-0.69 ppm at 40 days after transplantation, and 0.14-0.65 ppm at 60 days after transplantation. The highest concentration of 1.84 ppm was found in the sample of 20 days after transplantation from I_1T_7treatment combination and the lowest in I_2T_0 treatment combinations. Similarly, the highest Pconcentration of 0.69 ppm was found in the sample of 40 days after transplantation from I_1T_6 treatment combination and the lowest in I_1T_0 treatment combination. The highest concentration of 0.65 ppm P was found in the I_2T_6 treatment combination and the lowest in I_2T_0 treatment combination. There was a positive correlation between pore water P concentration and yield of rice. The highest pore-water K concentration of 12.47, 5.67 and 4.67 ppm were found at 20, 40 and 60 days after transplantation in the same treatment combination of I_2T_4 (saturated condition + 50% inorganic and 5 ton compost/ha) and the lowest concentration was found in I_2T_0 treatment combinations. Higher level of pore water K concentrations and yields were found in the treatment combinations of I_1T_4, I_2T_4 and I_2T_7 due to application of water hyacinth compost and poultry manure in combination of inorganic fertilizer.

Table 4.2.5 Interaction effect of irrigationandfertilizer on the pore-water N,P and K concentrations in root zone area

Treatments	Pore-water N conc.		Pore-water P conc.			Pore-water K conc.		
	20 DAT	40 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
I_1T_0	11.93de	9.27	0.55e	0.337	0.193gh	4.00	2.23	1.67d
I_1T_1	15.13b-e	14.47	1.24b	0.357	0.477a-d	6.67	3.33	2.33bcd
I_1T_2	19.20a	12.00	0.69e	0.470	0.530abc	9.34	2.56	2.17cd
I_1T_3	13.07cde	14.47	0.93cde	0.513	0.370c-g	7.78	4.00	3.17bc
I_1T_4	15.40b-e	16.33	0.84cde	0.557	0.240e-h	10.22	3.45	2.17cd
I_1T_5	15.40b-e	14.33	1.50ab	0.60	0.303d-h	9.11	3.89	2.0cd
I_1T_6	13.53cde	13.67	1.40abc	0.690	0.247e-h	10.44	5.33	3.17bc
I_1T_7	15.33b-e	17.13	1.84a	0.640	0.433b-e	8.22	3.56	2.50bcd
I_2T_0	11.67e	9.20	0.53e	0.390	0.137h	3.78	1.11	1.67d
I_2T_1	18.67ab	13.07	1.18bcd	0.483	0.230e-h	9.62	2.89	2.17cd
I_2T_2	15.87abc	14.67	0.93cde	0.610	0.213fgh	8.22	3.11	2.00cd
I_2T_3	15.67a-d	11.20	0.78de	0.497	0.423b-e	7.33	2.56	2.17cd
I_2T_4	16.80abc	12.13	1.59ab	0.523	0.410b-f	12.47	5.67	4.67a
I_2T_5	17.73ab	15.20	0.71de	0.570	0.240e-h	9.33	3.55	2.33bcd
I_2T_6	16.53abc	13.53	0.91cde	0.513	0.647a	7.11	4.22	2.67bcd
I_2T_7	17.87ab	14	1.55ab	0.577	0.583ab	9.11	3.44	3.50b
SE (±)	**1.03**	**NS**	**0.16**	**NS**	**0.06**	**NS**	**NS**	**0.35**

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

4.2.3 Effect of irrigation, fertilizer and manure on the N,P and K concentrations of pore-water in rice root zone (outside the core) and root free fallow area (inside the core) of core soil at flowering stage of boro rice

4.2.3.1 Effect of irrigation on the N,P and K concentrations of pore-water of root zone (outside the core) and root free fallow area(inside the core) of core soil at flowering stage of rice

The pore-water N, P and K concentrations were influenced by different irrigation management in the rice root zone area and root free area (Table 4.2.6). The almost similar concentrations of pore-water N and P were found in the rice root zone area (outside the core) and without rice root zone (into the core). In the root zone area, the higher pore-water P (1.01 ppm) and K (3.42 ppm) concentrations were found in the continuous flooded condition in comparison to saturated condition (0.80 ppm P, 2.54 ppm K). The higher pore-water K concentrations were found into the core where plant root was absent (Table 4.2.6). The fallow area (into the core) contains higher concentration of K at flowering stage of rice and it proves that higher levels of applied K stay in pore-water for a long duration in the surface soil. The higher levels of pore-water K concentrations were found inside the core where crop was not grown, and applied K remained in
the pore water in soluble form.

Table 4.2.6 Effect of irrigation on the pore-water N, P and K concentrations in root zone area (out side the core) and root free area (into the core) of soil at flowering stage of rice

Irrigation	Pore-water N in outside core	Pore-water N inside core	Pore-water P outside core	Pore-water P inside core	Pore-water K outside core	Pore-water K inside core (ppm)
I_1	15.64	16.18	1.01a	0.93	3.42a	10.50
I_2	18.67	15.44	0.80b	0.95	2.54b	10.21
SE (±)	NS	NS	0.03	NS	0.08	NS

I_1= Continuous flooded, I_2 = Saturated condition

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

Figure 4.7. Core installed in the middle of a plot and pore-water collection by rhizon sampler from boro rice field

4.2.3.2 Effect of fertilizer on the N,P and K concentrations of pore-water of root zone (outside the core) and root free fallow area(inside the core) of core at flowering stage of rice

The similar N and P concentrations were found in the root zone and root free areas during flowering stage of rice with different fertilizer treatments. The higher concentrations of N and P were found in the fertilizer treatments where fertilizer and manures were used. The pore water N concentrations varied in outside (13.90-18.20 ppm) and inside the core (12.33-17.70 ppm). The highest concentration of P (1.39 ppm) was found in the inside core pore water T_4 treatment where 50% NPKSZn + 5 ton compost/ha was used inside the core. The pore water P concentration varied in outside the core (0.43-1.26) and inside the core (0.45-1.39).The pore water K concentration varied in outside the core (2.00-3.50) and inside the core (9.01-11.54).The higher K concentrations were found in the pore-water of fallow area (into the core) where crop root was absent. The higher pore water concentrations inside the core indicated the presence of higher concentration of applied K in the solution for long duration due to absence of crop. The presence of higher levels K into the core soil at flowering stage indicated that applied K can stay longer time in the soil solution.

Table 4.2.7 Effect of fertilizer and manure on the pore-water N, P and K concentrations in root zone area (outside the core) and root free fallow area (into the core) at flowering stage of boro rice

Treatments	Pore-water N (ppm)		Pore-water P (ppm)		Pore-water K (ppm)	
	Outside core	Inside core	Outside core	Inside core	Outside core	Inside core
T_0	13.90	12.33	0.43	0.62b	2.00	9.01
T_1	18.20	15.30	0.98	1.35a	3.50	11.54
T_2	16.80	14.23	0.48	1.25a	2.50	9.65
T_3	16.57	15.07	0.98	0.48b	3.00	10.74
T_4	17.27	17.87	1.26	0.45b	3.33	10.26
T_5	18.20	15.83	1.13	0.94b	2.50	11.07
T_6	16.83	17.70	0.74	1.39a	2.50	10.00
T_7	17.50	15.17	1.04	1.04ab	3.50	10.54
SE (±)	NS	NS	NS	0.17	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

4.2.3.3 Interaction effect of irrigation and fertilizer on the N,P and K concentrations of pore-water of root zone (outside the core) and root free fallow area (inside the core) of core at flowering stage of rice

The combined effect of fertilizer and irrigation did not affect the pore-water N concentrations of root zone and fallow areas. Pore water N concentration varied from 13.47 to 20.07 ppm in the pore water of outside the core (root zone area) and 12.12 to 19.53 ppm) inside the core (fallow area). In the pore-water of root zone area, the highest P concentration of 1.70 ppm was found at flowering stage in the I_2T_5 treatment combination. In the pore-water of root free area, the highest P concentration of 2.43 ppm was found in the I_2T_6 treatment combination. The pore-water K concentrations of flowering stage of boro rice were not significantly affected by combined effect of irrigation and fertilizer and lower K concentrations were found in the root zone area in comparison to fallow area (into the core). In the fallow area, higher and significantly different K concentrations were found and the highest K concentration of 14.37 ppm was found in the I_1T_1 treatment combination (Table 4.2.8) and it was only 3.67 ppm in the root zone area of same treatment combination.

Table 4.2.8 Interaction effect of irrigation andfertilizeron the pore-water N, P and K concentrations in root zone area (outside the core) and root free fallow area (into the core) at flowering stage of boro rice

Treatments	Pore-water N (ppm)		Pore-water P (ppm)		Pore-water K (ppm)	
	Outside core	Inside core	Outside core	Inside core	Outside core	Inside core
I_1T_0	13.47	12.87	0.75bc	0.40b	2.67	8.00b
I_1T_1	16.33	15.40	1.35abc	2.03a	3.67	14.37a
I_1T_2	13.53	12.13	0.38c	2.04a	2.67	8.18b
I_1T_3	15.87	15.27	1.34abc	0.43b	4.00	11.67ab
I_1T_4	15.40	19.00	1.80a	0.38b	3.67	10.56ab
I_1T_5	17.27	15.33	0.56c	0.79b	2.33	12.52ab
I_1T_6	15.87	19.53	0.86abc	0.35b	3.00	10.74ab
I_1T_7	15.40	16.33	1.03abc	1.05b	**4.33**	8.96b
I_2T_0	16.33	14.80	0.50c	0.84b	2.33	12.04ab
I_2T_1	20.07	15.20	0.62c	0.68b	3.33	9.61b
I_2T_2	20.07	16.33	0.58c	0.45b	2.33	11.11ab
I_2T_3	17.27	14.87	0.63c	0.53b	2.00	9.82ab
I_2T_4	19.13	16.13	0.71bc	0.52b	3.00	9.96ab
I_2T_5	19.13	16.33	1.70ab	1.10b	2.67	9.63b
I_2T_6	17.80	15.87	0.62c	2.43a	2.00	9.26b
I_2T_7	19.60	14.00	1.04abc	1.03b	2.67	11.11ab
SE (±)	NS	NS	0.29	0.24	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

4.2.4 Effect of irrigation and fertilizer on the chemical properties of post experiment soil

4.2.4.1 Effect of irrigation, fertilizer and manure on the nutrient concentration and chemical properties of postexperimentsoil of root zone area (outside the core)

The similar levels of nutrient, organic matter were found in the post experiment soils of different irrigation treatment. The higher level of pH (6.8) were found in the soil of saturated irrigation compared to continuous flooded irrigation (pH 6.7) (Table 4.2.9).

The nutrient levels and chemical properties of postexperiment soils were influenced by application of different fertilizer and manure. The pH of post experiment soils increased where poultry manure was used with inorganic fertilizer and higher pH values were found in the treatments T_6(7.1) and T_7(7.1). The level of organic matter increased in the $T_2$to T_7 treatments due to application of organic plus inorganic fertilizer (Table 4.2.10). The highest % of organic matter (1.60) was found in the T_2treatment (50% NPKSZn + 5 ton cowdung ha^{-1}) which was statistically similar to $T_3$and T_6 treatments. The level of N, P and K increased more where manure and inorganic fertilizers were used. The highest concentration of available P (26.06 ppm) was found in the T_6 treatment and lowest in control treatment. The highest concentration of K(34.85 ppm) was found in T_4 treatment where 50% inorganic fertilizer plus 5 ton water hyacinth compost was used. The second highest available K (25.7 ppm) was found in T_6 and T_7 treatments where inorganic fertilizer plus poultry manure were used.

Table 4.2.9 Effect of irrigation on the nutrient concentration of post-experiment soil (outside the core)

Treatments	Soil pH	Organic matter(%)	Total N(%)	Available P(ppm)	Available K(ppm)
I_1	6.7a	1.39a	0.121	19.20	27.02
I_2	6.8b	1.48b	0.120	18.46	21.68
SE (±)	0.013	0.013	NS	NS	NS

I_1=Continuous flooded; I_2= Saturated condition

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

Table 4.2.10 Effect of fertilizer and manure on the soil nutrient concentration and chemical properties of post experiment soil (outside the core)

Treatments	Soil p^H	Organic matter (%)	Total N(%)	Available P (ppm)	Available K (ppm)
T_0	6.4c	1.10d	0.105d	12.14e	15.67d
T_1	6.6bc	1.20d	0.105d	16.88cd	19.54cd
T_2	6.7b	1.60a	0.12c	20.63bc	21.71bc
T_3	6.6b	1.55ab	0.123c	17.73bcd	27.27b
T_4	6.7b	1.41c	0.12c	19.53bcd	34.85a
T_5	6.7b	1.46bc	0.126bc	16.45d	24.24bc
T_6	7.1a	1.50abc	0.131ab	26.06a	25.76b
T_7	7.1a	1.47bc	0.132a	21.20b	25.76b
SE (±)	0.04	0.030	0.003	1.06	1.62

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

The highest pH (7.2) was found in I_2T_6 treatment combination and the lowest (6.3) in I_1T_0treatment combination. The level of organic matter in postexperiment soils were significantly influenced by combined effect of fertilizer and irrigation (Table 4.2.11).The higher levels of organic matter werefound in the treatments where fertilizer and manures were applied. The highest content of organic matter (1.64%) was found in the treatment combination of I_2T_2 (saturated condition + 50% inorganic fertilizer and 5 ton cowdung ha^{-1}) which was statistically similar to I_1T_2, I_1T_3, I_2T_3, I_2T_5, I_2T_6 and I_2T_7 treatment combinations where organic and inorganic fertilizers were used combinedly. Similarly the level of available P was significantly influenced by irrigation and fertilizer treatments and higher concentration of available P was found where fertilizer and manure were applied.

Table4.2.11 Interaction effects of irrigation and fertilizer on the nutrient concentration of post experiment soil (outside the core)

Treatments	Soil pH	Soil Organic matter (%)	Total N (%)	Available P (ppm)	Available K (ppm)
I_1T_0	6.3	1.12ef	0.095	12.14e	16.18
I_1T_1	6.5	1.14ef	0.090	18.24cd	18.18
I_1T_2	6.7	1.54ab	0.117	24.76ab	24.24
I_1T_3	6.6	1.58ab	0.128	20.05bcd	33.33
I_1T_4	6.7	1.30def	0.120	15.61de	36.36
I_1T_5	6.6	1.33def	0.129	17.20de	27.27
I_1T_6	7.0	1.45bcd	0.132	26.63a	30.30
I_1T_7	7.1	1.45bcd	0.131	19.93cd	30.30
I_2T_0	6.5	1.07f	0.090	12.13e	15.15
I_2T_1	6.7	1.26cde	0.092	15.52de	20.91
I_2T_2	6.6	1.64a	0.123	16.50de	19.18
I_2T_3	6.6	1.53ab	0.119	15.40de	21.21
I_2T_4	6.7	1.51abc	0.122	23.45abc	33.33
I_2T_5	6.8	1.58ab	0.122	15.70de	21.21
I_2T_6	7.2	1.55ab	0.129	25.50a	21.21
I_2T_7	7.0	1.50abc	0.137	23.46abc	21.21
SE (±)	NS	0.04	NS	1.50	NS

I_1=Continuous flooded; I_2= Saturated condition

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

The highest concentration of available P (26.63 ppm) was found in the treatment combination I_1T_6 which was statistically and closely similar to I_1T_2, I_2T_4, I_2T_6 and I_2T_7 treatment combinations. The higher concentrations of available K were found in the treatments of I_1T_3, I_1T_4, I_2T_3 and I_2T_4 treatment combinations where inorganic fertilizer and water hyacinth compost were used. Similarly highest N concentration (0.137%) was found in the I_2T_7 treatment combination which was statistically similar to other organic and inorganic fertilizer combinations.

4.2.4.2 Effect of irrigation, fertilizer and manure on the nutrient concentration and chemical properties of post-experiment inside core soil (fallow area)

The similar levels of nutrient, organic matter levels were found in the post-experiment inside core soils of different irrigation treatment but higher pH value was found in the soils of saturated irrigation. The soil organic matter, total N, available P and K of the soil of inside the core were not significantly influenced with the different irrigation (Table 4.2.12). The nutrient levels and chemical properties of postexperiment soils were influenced by application of different fertilizer and manures. The pH of post experiment soils increased where poultry manure was used with inorganic fertilizer and higher pH values were found in the treatments T_6 and T_7 which changes were similar to the post harvest rice field soils of another experiment and net house experiment. The level of organic matter increased in the $T_2$to T_7 treatments due to application of organic plus inorganic fertilizer. The highest content of organic matter (1.59) was found in the T_2 treatment (50% NPKSZn + 5 ton cowdung ha^{-1}) which was statistically similar to T_3 to T_7 treatments (Table 4.2.13). The treatment wise increases of OM levels were desimilar in the soils of rice field and fallow area of the core. The level of P and K concentrations increased more in the post experiment soils of inside the core where plants were absent. Treatment wise higher levels of P and K increased in the core soil where manure and inorganic fertilizers were used. The highest concentration44.72 ppm available P was found in the T_7 treatment of inside soil and 21.20 ppm was found in the same treatment of rice root zone area soils (outside the core). The lowest concentration of 22.89 ppm was found in control treatment of core soil and 12.14 ppm was found in the control treatment of post-experiment root zone area soil. The highest concentration of 63.64 ppm K was found in the core soils of T_5 treatment where 70% inorganic fertilizer plus 3 ton compost was used during rice cropping but only 24.24 ppm available K was found in the post-harvest root zone area soils of same treatment. The core soils K concentration increased around 2 fold compared to the soils of post experiment field soils (outside the core) with rice. This findings indicates that higher amount of applied P and K present in the surface soil for the long time.

Table 4.2.12 Effect of irrigation on the nutrient concentration of post-experiment (inside the core) soil

Treatments	Soil pH	Soil Organic matter (%)	Total N (%)	Available P (ppm)	Available K (ppm)
I_1	6.66a	1.31	0.121	19.20	47.73
I_2	6.80b	1.33	0.120	18.46	49.58
SE (±)	**0.013**	**NS**	**NS**	**NS**	**NS**

I_1=Continuous flooded; I_2= Saturated condition

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

Table 4.2.13 Effect of fertilizer and manure on the nutrient concentrations and chemical properties of post-experiment core soil (fallow area)

Treatments	Soil pH	Organic matter (%)	Total N(%)	Available P (ppm)	Available K (ppm)
T_0	6.5b	1.07c	0.098	22.89c	22.58c
T_1	6.7b	1.06c	0.095	33.39b	54.55ab
T_2	6.7b	1.59a	0.126	31.84bc	45.45b
T_3	6.6b	1.40b	0.123	34.41b	62.12a
T_4	6.7b	1.37b	0.119	30.11bc	46.97b
T_5	6.6b	1.38b	0.126	31.34bc	63.64a
T_6	7.1a	1.31b	0.125	39.00ab	50.00ab
T_7	7.0a	1.41b	0.125	44.72a	43.94b
SE (±)	**0.057**	**0.049**	**NS**	**2.60**	**4.24**

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

The level of organic matter in post experiment core soils were influenced by combined effect of fertilizer and irrigation. The higher levels of organic matter were found in the treatments where fertilizer and manures were applied. The highest content of organic matter (1.61%) was found in the treatment combination of I_2T_2 (saturated condition + 50% inorganic fertilizer and 5 ton cowdung ha^{-1}) which was closely similar to I_1T_2, I_1T_3, I_2T_4, I_2T_7 treatment combinations where organic and inorganic fertilizers were used combinedly. The N concentration over the treatment combination varied 0.096-0.128% and higher N levels were found where inorganic plus manure were applied. The highest concentration (47.34 ppm) of available P was found in I_2T_7 treatment combination and the lowest in I_1T_0 treatment combination. The level of P more increased where poultry manure was applied with inorganic fertilizer. Similarly the level of available K was significantly influenced by irrigation and fertilizer treatments and higher concentration of available K was found where fertilizer and manure were applied.The higher concentrations of available K was found in the treatment combinations of core soils compared to post-harvest field soils (outside the core). The highest concentration of 66.63 ppm available K was found in the treatment combination I_1T_5 (Continuous flooded + 70% inorganic fertilizer and 3 ton compost ha^{-1}) which was statistically and closely similar to I_1T_3, I_2T_3, I_2T_6 and I_2T_5 treatment combinations (Table 4.2.14) and which was 27.27 ppm in the post experiment soils of cropped area. Similarly higher available P concentrations were found in the post experiment core soils (fallow area) in comparison to the soils of cropped area.

Table4.2.14 Interaction effects of irrigation and fertilizer on the nutrient concentration of post-experiment core soil (fallow area)

Treatments	Soil pH	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (ppm)
I_1T_0	6.3	0.993	0.096	22.11	27.27ef
I_1T_1	6.5	1.09	0.105	37.56	57.58abc
I_1T_2	6.7	1.56	0.128	26.22	33.33def
I_1T_3	6.6	1.54	0.126	35.03	60.61ab
I_1T_4	6.7	1.31	0.123	30.89	54.55a-d
I_1T_5	6.6	1.32	0.128	34.78	66.67a
I_1T_6	7.0	1.30	0.129	37.45	45.45a-e
I_1T_7	7.1	1.38	0.128	42.11	36.36c-f

I_2T_0	6.5	1.14	0.107	23.66	17.88f
I_2T_1	6.7	1.03	0.098	29.22	51.51a-d
I_2T_2	6.6	1.61	0.126	37.45	57.58abc
I_2T_3	6.6	1.263	0.122	33.78	63.64a
I_2T_4	6.7	1.430	0.113	29.33	39.39b-e
I_2T_5	6.8	1.440	0.125	27.89	60.61ab
I_2T_6	7.2	1.320	0.120	40.78	54.55a-d
I_2T_7	7.0	1.440	0.123	47.34	51.51a-d
SE (±)	NS	NS	NS	NS	6.00

I_1=Continuous flooded; I_2= Saturated condition

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

4.2.5 General Discussion

The growth and yield of rice crops were not significantly affected by irrigation in both experiment but higher yields were obtained in continuous flooded irrigation in comparison to other irrigation treatments. The effect of residual and renewal added of fertilizer and manure influenced the pore-water nutrient availability, rice yield and the fertility of postexperiment soils. The higher grain yields were obtained in inorganic plus organic treatments. The higher grain yield was obtained from T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure ha^{-1} was added. The poultry manure performed better compared to compost and cowdung, for increasing the yield of boro rice. The concentration of available N, Pand K in the pore-water varied with irrigation, fertilizer, manure, cropped and without cropped area and time of pore-water collection. The higher concentrations of N, P and K were found in the pore-water of T_6 and T_7 treatments where poultry manure plus inorganic fertilizers were used and higher yields were also obtained. There was a positive correlation between pore-water nutrient concentration and yield of rice. Pore-water P concentration decreased with increasing days after transplantation. Higher concentrations of pore-water K were found into the core (fallow area) than rice root zone area (outside) during the cropping season. Higher soil fertility improvement was found in the post-harvest soils where manure was applied in rice cultivation.The higher level of organic matter (1.60%) was found in the T_2 treatment (50% NPKSZn + 5 ton cowdung ha^{-1}) which was closely similar to other organic plus inorganic treatments T_3 and T_6 and it was only 1.20%in T_1 (RDCF) treatment. The level of soil N,P and

K concentration increased where manure plus inorganic fertilizers were used. The treatment wise increase of OM levels was similar in the soils of rice field and fallow area of the core. Higher levels of P and K increased in the core soil where plant was absent. The core soils K concentration increased around 2 fold compared to the soils of post harvest soils of outside the core. Similarly higher available P was obtained in the core soil (fallow area) than the soils of core area.The application of poultry manure increased the pH of the soil.

4. 3 (Experiment 3) Integrated use of fertilizer and manure on rice yield, soil fertility and nutrient availability under different irrigation management system in rice – rice cropping pattern

The results obtained from the experiment three on integrated use of fertilizer and manure with different water management on rice yield, soil fertility and nutrient availability under rice-rice cropping system are presented and explained here.

4.3.1 Effects of irrigation, fertilizer and manure on the growth and yield of T. aman rice

4.3.1.1 Effects of irrigation, fertilizer and manure on the growth and yield of T. aman rice

The results showed that the yield and yield parameters of T. aman rice were not significantly influenced by irrigation but significantly influenced by fertilizer and manure application (Table 4.3.1). Among the different fertilizer treatments, T_6 (50% NPKSZn + 3.5 ton PM ha^{-1}) showed the highest plant height (123.2 cm), which was statistically similar to all fertilizer treatments except T_0 where fertilizer was not applied. The highest panicle length (25.26 cm), filled grains $panicle^{-1}$ (88.1) and 1000 grain weight (21.22 g) were found in the T_5, T_3 and T_7 treatments respectively where organic and inorganic fertilizers were used. The lowest plant height, number of effective tillers/hill, filled grains $panicle^{-1}$were observed in T_0 treatment where no fertilizer was used.

Different fertilizer and manure treatments showed significant variations in respect of grain and straw yields (Table 4.3.1). The application of fertilizers and manure had a positive effect on the grain and straw yield of T. aman rice. The highest straw yield (6.26 t ha^{-1}) was obtained in residual and renewal effect of T_5 (70% NPKS + 3 ton compost ha^{-1}) treatment which was statistically similar to all other treatments except T_0 treatment. The lowest straw yield was obtained in T_0 treatment.

The highest grain yield (4.48 t ha^{-1}) was observed in the T_2 treatment where 50% NPKS + 5 ton cowdung ha^{-1} was used which was statistically similar to all other treatment except T_0 (control). The lowest grain yield (3.79 t ha^{-1}) was observed with T_0 where no fertilizer was applied. The combined effects of different doses of fertilizer and irrigation on the grain and straw yield of rice were not significantly different.

Table 4.3.1 Effect of fertilizer and manure on the yield parameters and yield of T. aman rice

Treatments	Plant height (cm)	Panicle length (cm)	No. of filled grain/panicle	1000 seed weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_0	104.9b	21.78c	68.37b	19.56c	3.47b	4.42b
T_1	118.6a	24.46ab	85.42a	20.78ab	4.34a	6.03a
T_2	120.7a	24.46ab	87.93a	20.22bc	4.48a	5.78a
T_3	120.8a	24.77ab	88.09a	20.44abc	4.40a	6.02a
T_4	119.9a	23.99b	83.69a	21.11ab	4.32a	5.94a
T_5	118.9a	25.26a	84.71a	21.00ab	4.09a	6.26a
T_6	123.2a	24.29b	84.77a	20.89ab	4.07a	5.82a
T_7	119.3a	24.36ab	78.84a	21.22a	4.18a	5.92a
SE (±)	2.13	0.25	3.12	0.25	0.14	0.24

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

4.3.1.2 Interaction effect of fertilizer and manure on the grain and straw yield of T. aman rice

The plant height, panicle length, number of filled grains $panicle^{-1}$, 1000 grainweight were not significantly influenced by interaction effect of irrigation and fertilizer. The grain and straw yields were significantly influenced by irrigation and fertilizer treatments. The highest straw yield (7.2 t ha^{-1}) was found in I_1T_5 treatment combination which was statistically similar to I_1T_7, I_2T_1, I_2T_2 and I_2T_3 treatment combination. The highest grain yield of 5.35 t ha^{-1} was recorded in I_2T_2 treatment combination which was statistically comparable to I_1T_5, I_1T_7, I_2T_1, I_2T_3 and I_3T_4treatment combination (Table 4.3.2). From the results of this experiment, it indicates that higher yields were obtained in the treatment combinations where inorganic fertilizers and manures were applied in the previous rice crops with integrated plant nutrient management.

Table 4.3.2 Interaction effect of irrigation, fertilizer and manure on the yield parameters of T. aman rice

Treatments	Plant height (cm)	Panicle length (cm)	No. of Filled grain/panicle	1000 seed weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_1T_0	104.27	20.99	64.50	19.33	3.35h	4.45fg
I_1T_1	118.23	23.78	78.07	20.67	3.96d-h	5.71b-f
I_1T_2	120.63	23.97	83.43	20.33	3.97d-h	5.28c-g
I_1T_3	122.30	24.88	89.47	20.67	3.80d-h	5.51b-g
I_1T_4	123.03	24.19	85.03	21.00	4.37b-f	5.61b-g
I_1T_5	121.40	25.29	86.47	21.00	4.84abc	7.21a
I_1T_6	122.57	24.45	88.70	21.33	3.90d-h	5.34c-g
I_1T_7	119.93	24.19	77.20	20.67	4.56a-d	6.72abc
I_2T_0	105.07	22.74	75.30	20.00	3.58fgh	4.65efg
I_2T_1	121.67	24.71	92.77	20.67	4.87abc	6.65a-d
I_2T_2	123.70	25.02	97.83	20.33	5.35a	6.88ab
I_2T_3	118.57	24.61	90.07	20.00	5.09ab	6.70abc
I_2T_4	112.00	24.05	88.80	21.67	4.02d-h	5.79a-e
I_2T_5	119.07	24.74	82.93	21.33	3.67e-h	5.90a-e
I_2T_6	125.40	24.35	86.80	20.33	3.91d-h	6.13a-d
I_2T_7	116.73	25.06	78.03	21.67	4.11c-h	5.63b-f
I_3T_0	105.50	21.60	65.30	19.33	3.47gh	4.16g
I_3T_1	115.77	24.89	85.43	21.00	4.21c-g	5.75a-f
I_3T_2	117.77	24.38	82.53	20.00	4.13c-h	5.20d-g
I_3T_3	121.43	24.81	84.73	20.67	4.31b-f	5.84a-f
I_3T_4	124.57	23.74	77.23	20.67	4.56a-d	6.42a-d
I_3T_5	116.30	25.74	84.73	20.67	3.77d-h	5.67b-f
I_3T_6	121.70	24.07	78.80	21.00	4.42b-e	6.00a-e
I_3T_7	121.33	23.84	81.30	21.33	3.89d-h	5.42b-g
SE (±)	NS	NS	NS	NS	0.24	0.42

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

4.3.2 Effects of irrigation, fertilizer and manure on the growth and yield of boro rice

4.3.2.1 Effects of irrigation, on the yield parameter and yield of boro rice

The number of effective tiller hill^{-1}, plant height, number of filled grains panicle^{-1} and grain yields were not significantly influenced by different levels of irrigation management. The highest grain yield (7.11 t ha^{-1}) was found in I_1(continuous flooded) treatment and the lowest(6.87 t ha^{-1}) in alternate wetting and drying (I_3) irrigation treatment. The straw yield was significantly influenced by irrigation and highest straw yield (7.51t ha^{-1}) was obtained in continuous flooded condition (Table 4.3.3).

Table 4.3.3 Effect of irrigation on the growth and yield parameters of boro rice

Treatments	No. of effective tiller hill^{-1}	Plant height (cm)	Panicle length (cm)	No. of filled grains panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_1	13.64	77.40	22.29b	93.48	7.11a	7.51b
I_2	13.18	76.82	21.62a	98.23	6.98b	7.22a
I_3	13.58	76.36	21.75a	98.42	6.87b	7.24a
SE (±)	**NS**	**NS**	**0.18**	**NS**	**NS**	**0.08**

I_1=Continuous flooded; I_2= Saturated condition; I_3= Alternate wetting and drying

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

4.3.2.2 Effects of fertilizer and manure on the growth and yield of boro rice

The different fertilizers and manures significantly influenced yield parameters of Boro rice (Table 4.3.4). The highest number of effective tillers hill^{-1} (14.4) was found in T_1 (100% NPKSZn) treatment and higher plant height, panicle lengths were found in organic plus inorganic fertilizer treatments. The lowest number of effective tillers/hill, plant height, filled grains panicle^{-1}were observed in T_0 treatment where no fertilizer was used. The higher number of filled grains panicle^{-1}(108.5) was found in T_6 which was statistically similar to T_4, T_7, T_3, T_5 and T_1tretments.

Table 4.3.4 Effect of fertilizer and manure on the yield parameter and yield of boro rice

Treatments	No.of effective tillers $hill^{-1}$	Plant height (cm)	Panicle length (cm)	No. of filled grains $panicle^{-1}$
T_0	10.80b	70.91	20.53b	78.3c
T_1	14.36a	78.31	22.30a	94.4abc
T_2	14.09a	78.37	22.28a	90.1bc
T_3	13.53a	76.13	21.64ab	100.8ab
T_4	13.40a	76.69	21.95a	103.2ab
T_5	14.07a	79.02	22.01a	95.7abc
T_6	13.62a	78.21	22.50a	108.5a
T_7	13.87a	77.22	21.87a	102.5ab
SE (±)	**0.43**	**0.86**	**0.38**	**4.93**

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

Different fertilizer and manure treatments showed significant variations in the grain and straw yields (Table 4.3.4). The application of fertilizers and manure had a positive effect on the grain and straw yield of boro rice. The highest straw yield (7.78 t ha^{-1}) was obtained in T_1 (Recommended dose of chemical fertilizer) treatment which was statistically similar to all other treatments except control. The lowest straw yield was obtained in T_0treatment.The highest grain yield (7.78 t ha^{-1}) was observed in the T_1 treatment where 100% recommended dose of fertilizer was used which was closely similar (7.71 t ha^{-1}) with the T_7 (70% NPKS + 2.1 ton poultry manure ha^{-1}) treatment. The lowest grain yield (5.02 t ha^{-1}) was observed with T_0 treatment where no fertilizer was applied.

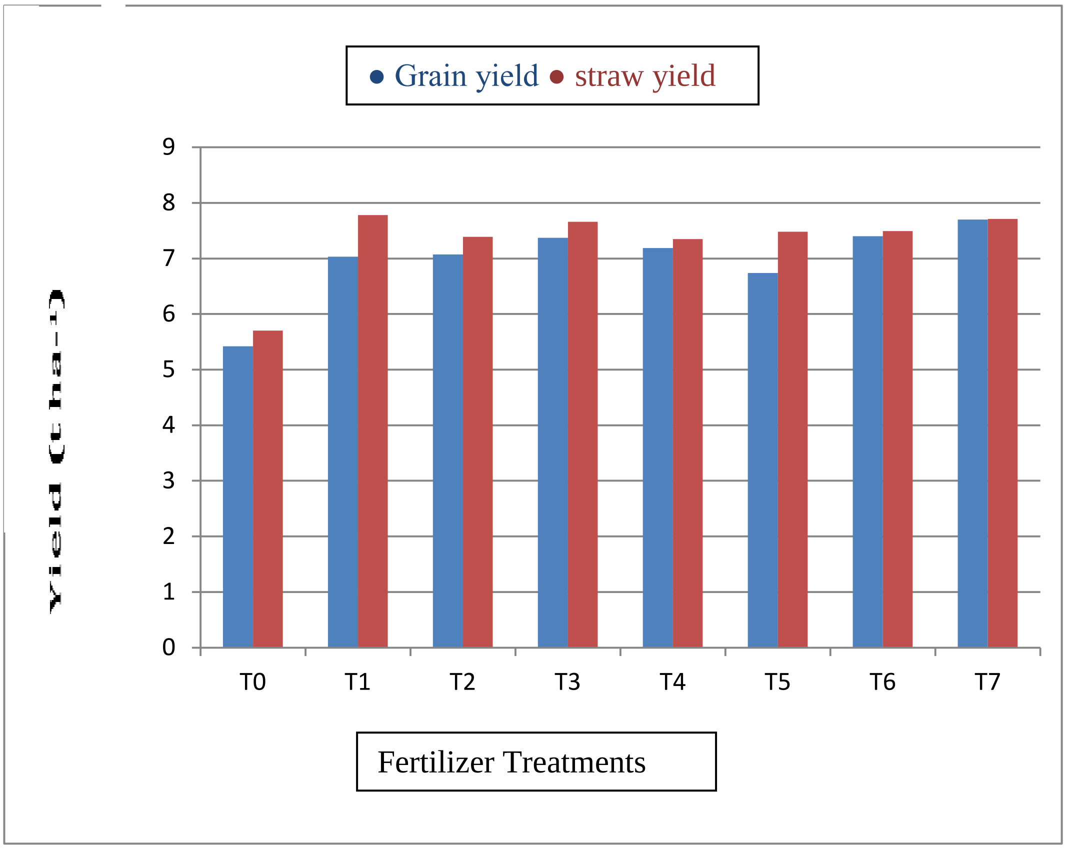


Figure 4.8 Effect of fertilizer and manure on the yield of boro rice

4.3.2.3 Interaction effect of irrigation and fertilizer on the grain and straw yields of boro rice

The number of effective tillers hill^{-1},panicle length and straw yield of rice were not significantlyaffected by the combined application of different fertilizer and irrigation treatments (Table4.3.5). The highest straw yield (8.26 t ha^{-1}) was obtained from I_1T_3 (continuous flooded condition + 70% NPKSZn + 3 ton cowdung ha^{-1}) treatment combination which was similar to I_1T_7 and I_1T_2 treatment combination. The highest grain yield of rice (7.94t ha^{-1}) was recorded with the treatment combination I_1T_7 (continuous flooded + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}), which was statistically similar to I_2T_7, I_3T_6 and I_3T_7 treatment combination. On the other hand, the lowest grain yield (5.26t ha^{-1}) was found in I_2T_0 (continuous flooded condition + control treatment) treatment combination.

Table 4.3.5 Interaction effect of irrigation and fertilizer on the growth and yield of boro rice

Treatmentcombinations	No. of effective tillers hill^{-1}	Plant height (cm)	Panicle length (cm)	No. of filled grains panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_1T_0	10.67	69.73h	21.15	70.4g	5.60i	6.10
I_1T_1	14.33	78.78a-d	22.43	74.3fg	6.71gh	7.65
I_1T_2	13.87	77.60a-e	23.06	82.6d-g	7.08c-h	7.78
I_1T_3	13.33	81.60a	23.38	119.6a	7.73ab	8.26
I_1T_4	13.87	77.62a-e	21.81	96.5a-g	7.60abc	7.59
I_1T_5	14.67	79.43abc	21.74	86.1b-g	5.77i	7.19
I_1T_6	14.40	75.98b-f	22.63	108.0a-e	7.72ab	7.66
I_1T_7	14.0	78.47a-d	22.09	110.5a-e	7.94a	7.83
I_2T_0	10.0	72.43fgh	20.55	80.8efg	5.26i	5.43
I_2T_1	14.73	77.63a-e	22.15	111.4a-d	7.50a-e	7.95
I_2T_2	14.73	77.62a-e	21.25	85.1b-g	6.99d-h	7.19
I_2T_3	14.13	74.20d-h	20.54	97.8a-g	7.16b-g	7.29
I_2T_4	12.07	77.31a-f	22.31	112.8abc	7.40a-f	7.37
I_2T_5	13.53	81.66a	22.37	103.8a-f	7.14b-h	7.55
I_2T_6	13.87	77.87a-d	21.87	103.8a-f	6.93e-h	7.31
I_2T_7	12.33	75.83b-f	21.90	90.3a-g	7.53a-d	7.65

I_3T_0	11.73	70.58gh	19.88	83.8c-g	5.38i	5.59
I_3T_1	14.00	78.53a-d	22.33	97.6a-g	6.87fgh	7.74
I_3T_2	13.67	79.88abc	22.54	102.7a-f	7.15b-h	7.20
I_3T_3	13.13	72.58e-h	20.99	85.1b-g	7.22b-g	7.43
I_3T_4	14.27	75.16c-g	21.71	100.4a-f	6.56h	7.10
I_3T_5	14.00	75.96b-f	21.92	97.4a-g	7.30b-g	7.70
I_3T_6	12.60	80.78ab	23.00	113.7ab	7.55a-d	7.50
I_3T_7	15.27	77.36a-f	21.62	106.6a-e	7.62abc	7.66
SE (±)	**NS**	**1.49**	**NS**	**4.93**	**0.17**	**NS**

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

4.3.3 Effect of irrigation, fertilizer and manure on the nutrient concentration and chemical properties of postexperimentfield soil

The application of manure and fertilizer in the boro seasons and previous application in rice cropping influenced the OM content in soil. The lower level of OM matter was found in the post-experiment soils of T_0 (control) and T_1 (RDCF) treatments. The increase of OM level was almost similar in all the treatment where organic plus inorganic fertilizerwere used. Similarly, higher levels of available P were found in the T_2-T_7 treatments where organic plus inorganic fertilizers were used. The highest P concentration was found in the T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure/ha used and that was statistically similar to $T_{6,}$ T_5 and T_2 treatments. The levels of soil N and K concentrations were increased more where inorganic and organic fertilizers were used. The highest K concentration was found in T_5 treatment where 70% inorganic fertilizer and 3 t ha^{-1} water hyacinth compost were usedwhich was statistically similar to all the treatments except control. The pH of post-harvest soils increased in T_6 and T_7 treatments where poultry manure was applied in combination with fertilizer (Table 4.3.6).

Table 4.3.6 Effect of fertilizer and manure on the nutrient concentration and chemical properties of post-experiment field soil

Treatments	Soil pH	Organic matter (%)	Total N(%)	Available P (ppm)	Available K (ppm)
T_0	6.6b	1.08c	0.079	11.23d	19.56c
T_1	6.6b	1.15bc	0.088	13.62c	28.33ab
T_2	6.6b	1.33a	0.096	15.80abc	29.44ab
T_3	6.6b	1.32a	0.096	13.82c	27.33b
T_4	6.6b	1.2a	0.092	14.26bc	30.11ab
T_5	6.5b	1.33a	0.102	15.21abc	31.94a
T_6	6.9a	1.31a	0.089	16.50ab	28.44ab
T_7	6.7ab	1.27ab	0.090	16.59a	29.61ab
SE (±)	**0.06**	**0.037**	**NS**	**0.632**	**1.12**

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

4.3.4 General Discussion

The T. aman and boro rice yield and yield parameters were influenced with the application of different irrigation and fertilizer. The yield and yield parameters of T. aman rice were not significantly affected by irrigation. T. aman rice yield and yield parameters were significantly affected by different fertilizer treatments. The highest T. aman rice yield was found from T_2 treatment and second highest was obtained from T_3 treatment where inorganic fertilizer and cowdung were applied and yields were increased due to positive effect of integrated nutrientmanagement applied in the previous rice crops. The higher grain yields of boro rice were found in the treatment combinations where inorganic fertilizers plus poultry manure with different irrigation levels were applied. The interaction effect of irrigation and fertilizer did not influenced the yield and yield parameters of T. aman rice. The pH of 6.9 was obtained in the soil where inorganic fertilizer and poultry manure were applied. The levels of organic matter, nitrogen and available P significantly increased in the treatments where fertilizer plus manure were applied.

CHAPTER 5

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

Three experiments were conducted at the Soil Science Department and research field of Sher-e-Bangla Agricultural University during January 2013 to June 2014 to study the effects of Fertilizer, Manure and Water Management on the Nutrient Availability, Leaching, Soil Fertility and Productivity under Rice-Rice Cropping Pattern.

5.1 (Experiment 1) Effects of fertilizer, manure and irrigation on nutrient contents in leachate and yield of rice

A net house experiment involving 2 irrigations and 5 fertilizer treatments were applied in undisturbed soil columns during January 2013-December 2013, with Boro and T. Aman grown season in sequence, to examine the effect of added fertilizer and manure on rice culture. BRRI dhan29 was used as the test crop in this experiment. BRRI dhan33 was used for T.Aman season. This experiment was laid out in Randomized Complete Block Design (RCBD) having 3 replications. This experiment was started during Boro rice season of the year 2013. A total 30 soil cores were collected (2 irrigation x 5 fertilizer x 3 replication) and soil cores were placed on the plastic containers. The leachate collection system was developed for collecting leachate passed through the rice cultivated soil columns. Fertilizer, manure and irrigation treatments were applied in the soils of the core during the Boro and T. Aman rice cultivation. The treatment were [(i) Control ii) Recommended dose of fertilizer. iii) 50% NPKSZn + 5 ton cowdung ha^{-1} iv) 50% NPKSZn + 5 ton compost ha^{-1} v) 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}] in combination with 2 levels of irrigation [(i) traditional irrigation i.e. continuous flooding (2-3 cm water)] and (ii) saturated condition].

The higher leachate N concentrations were found in the saturated irrigation treatment compared to continuous flooded condition. The highest leachate N concentration (6.44 mg/L) was obtained at 60 days after transplantation where saturated irrigation was applied (I_2) and lowest leachate N concentration was obtained at I_1 treatment at 40 days after transplantation. The leachate P concentrations were significantly affected by fertilizer treatments and decreased with increasing days after transplantation (DAT).

Among leachate samples of different dates, higher N concentrations were found in the leachate of 60 days after transplantation of boro rice in comparison to the lechate of 20 and 40 days after transplantation. The N leaching increased at 60 days after transplantation during boro rice growing season and the highest N concentration (6.44 ppm) obtained in the leachate of I_2 treatment at 60 days after transplantation. The lechate P concentration varied with time and irrigation treatment. The higher P concentrations were obtained in saturated irrigation (I_2) treatment. The leachate P concentration decreased with increased days after transplantations. In I_1 and I_2 irrigation treatments, 4-5 times lower levels of P concentrations were obtained in the lechate of 40 and 60 days after transplantation in comparison to the leachate samples of 20 days after transplantation. The highest P concentration (1.64 ppm) was found in the leachate of I_2 irrigation treatment at 20 days after transplantation and lowest (0.303 ppm) was found in the leachate of I_2 irrigation treatment at 60 days after transplantation. The leachate P concentration decreased with increasing time may be due to increased fixation with soil colloids. The lower nutrient concentrations in the continuous flooded irrigation due to more diluted N and P in presence of higher amount of water and in soil.

The leachate N and P concentration increased with the application of fertilizer treatments. In all the treatments higher levels of leachate, N were obtained at 60 days after transplantation. The highest leachate N concentration (7.07 ppm) was found in T_1 treatment at 60 days after transplantation and lowest (2.60 ppm) at 40 days after transplantation. The higher leachate N concentrations were found in T_1 treatment due to higher solubility of inorganic fertilizers, and the date was closer to the date of N application. The leachate N concentrations at 20 days after transplantation were significantly influenced with the interaction of irrigation and fertilizers and almost similar leachate N concentrations were found in all the treatment combinations except I_1T_0. The highest leachate N concentration (7.93 ppm) was found in I_2T_4 treatment combination which was similar to I_2T_1 treatment combination.

The leachate P concentrations of different dates were significantly influenced with the application of different fertilizer treatments in the boro rice. The higher leachate P concentrations were found at 20 days after transplantation and decreased with increasing time. The highest P (1.72 ppm) was obtained in the leachate of T_1 treatment which was statistically similar to all other fertilizer treatments except T_0 treatment. The higher leachate P concentrations were found in the T_4 treatment which was statistically similar with all other treatments except T_0 treatment. At 20 days after transplantation the highest leachate P concentrations (2.09 ppm) was found in I_2T_1 treatment combination. At 40 and 60 days after transplantation, the comparatively higher levels of leachate P concentrations were observed in I_1T_1, I_1T_4 and I_2T_4 treatment combinations, than other treatment combinations.

The leachate K and S concentrations of 20 days after transplantation of boro rice were significantly influenced by different irrigation treatments. The highest K (4.78 ppm) concentration was found in I_2 (saturated condition) treatment at 20 days after transplantation and lowest (1.68 ppm) in continuous flooded condition (I_1) (Table 4.1.4) in the leachate at 60 days after transplantation of boro rice. The leachate K concentration was decreased with increasing days after transplantation. The K and S leaching were significantly influenced by different fertilizer treatments applied in boro rice. The higher concentrations of K (4.86 ppm) was found in the T_4 treatment (50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) which was closely similar to T_1 treatment and the lowest K (1.60 ppm) leaching was found in the T_0 (control) treatment. The leachate S concentration increased with increasing days after transplantation. The leachate S concentration over the dates and fertilizer treatments varied from 1.31-2.51 ppm. The highest leachate S concentration (2.51 ppm) was found in T_1 treatment which was statistically and closely similar to T_4 treatment and lowest was obtained in T_0 treatment.

The K and S concentrations in the leachate were positively correlated with grain and straw yields of boro rice. The range of K leaching varied from 1.46 to 6.20 ppm. The highest leachate K concentration was found in the I_2T_1 (saturated condition plus recommended dose of fertilizer) treatment combination which was closely similar to I_2T_2, I_2T_3 and I_2T_4 treatment combinations and lowest in I_1T_0 treatment combination. The K concentration decreased with increasing days after transplantation.

The interaction effect of irrigation and fertilizer were not significantly influenced the leachate S concentration. The higher levels of S leaching were observed in most of the treatment combinations at 40 days after transplantation in comparison to 20 days after transplantation. The leachate S concentration varied 1.14-3.13 ppm over the dates and treatment combinations. The highest leachate S concentration (3.13 ppm) was obtained in I_2T_2 treatment combination and lowest (1.14 ppm) in I_1T_0 treatment combinations

The plant height, panicle length, filled grains $panicle^{-1}$, unfilled grain, 1000 grain weight were not significantly affected by irrigation but the grain and straw yields of boro rice were significantly influenced by irrigation. The higher plant height, filled grains/panicle and 1000 grain weight were obtained in the continuous flooded condition in comparison to saturated condition. The higher grain (76.03 g $core^{-1}$**)** and straw yield (64.75 g $core^{-1}$) were obtained in the continuous flooded (I_1) irrigation than saturated condition (I_2).

The plant height and panicle length were significantly influenced by fertilizer treatments but filled grains panicle^{-1} and 1000 grain weight were not significantly affected by fertilizer treatments. The highest plant height (78.10 cm) was found in T_2 (50% NPKSZn + 5 ton cowdung ha^{-1}) treatment which was statistically similar to all other treatment except control. The T_4 (50% NPKS+ 3.5 ton poultry manure ha^{-1}) treatment gave the tallest panicle length (23.63 cm) and lowest in control treatment. The grain and straw yields of boro rice were significantly influenced by fertilizer treatments. The highest grain yield (88.42g core^{-1}) was found in T_1 (RDCF) treatment which was closely similar to T_4 (88.32 g core^{-1}) treatment and lowest was obtained from control treatment. Higher level of N, P and K concentrations were found in the leachate of T_1 and T_4 treatments. Similarly, the highest straw yield was found in T_1 treatment which was statistically similar to all other treatments except control.

The yield parameters and straw yields of boro rice were not significantly influenced by the interaction effect of fertilizer and irrigation but the grain yields were significantly influenced with the interaction effects of fertilizer and irrigation. The highest grain yield (92.77g core^{-1}) of boro rice was obtained from I_1T_4 (continuous flooded + 50% NPKSZn+ 3.5 ton poultry manure ha^{-1}) treatment combination which was statistically comparable to I_1T_1 (continuous flooded + RDCF), I_1T_2 (continuous flooded + 50% NPKSZn + 5 ton cowdung ha^{-1}), I_1T_3 (continuous flooded + 50% NPKSZn+ 5 ton compost ha^{-1}) and I_2T_4 (saturated condition plus 50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment combination and lowest grain yield was found from I_2T_0 (saturated condition and fertilizer control) treatment combination

In case of T aman rice growing period the leachate N concentrations increased at 40 days after transplantation in comparison to 20 days after transplantation and opposite trend was observed for P and K. Higher concentrations of P in the leachate of 20 days after transplantation was found in the I_1 (continuous flooded) treatment and lower concentration saturated soil condition. The concentrations of K in the leachate were significantly influenced by irrigation treatments. The higher concentrations of leachate K were found in the saturated condition (I_2) than the leachate samples of continuous flooded irrigation. The leached P and K concentrations decreased at 40 days after transplantation and very low levels of P were found in the leachate of 40 days after transplantation may be due to rapid precipitation with the soil colloid.

The leachate N, P and K concentrations were significantly influenced by fertilizer treatments. The highest N concentration in the leachate (4.27 ppm) was found in the T_1 (Recommended dose of fertilizer) treatment of the samples of 20 days after transplantation and lowest in the control treatment. At 40 days after transplantation, the highest N concentration (5.60 ppm) was found in T_1 treatment which was statistically similar to the T_2 (50% NPKS+ 5 ton cowdung ha^{-1}) and T_3 (50% NPKSZn + 5 ton compost ha^{-1}) treatments. The P leaching decreased with increasing days after transplantation. At 20 days after transplantation, the highest P concentration of 3.17 ppm was found in the T_2 treatment and the same treatment contains only 0.02 ppm P at 40 days after transplantation and similar leachate P concentrations were found in all other fertilizer treatments. The leachate K concentration moderately decreased with increasing days after transplantation. At 20 days after transplantation the highest concentration of leachate K (1.43 ppm) was found in T_3 (50% NPKSZn + 5 ton compost ha^{-1}) treatment which was statistically similar to all other treatments except control (T_0). At 40 days after transplantation, the highest K concentration (1.21ppm) was found in the T_4 treatment and higher grain yield was recorded from this treatment.

The yields were correlated with the leachate N, P and K concentrations. The N, P and K concentrations were significantly influenced by the interaction effects of irrigation and fertilizer. At 20 days after transplantation, the leachate N ranged from 1.63- 4.27 ppm, P ranged from 1.50 to 4.27 ppm and leachate K ranged from 0.56-2.02 ppm. At 20 days after transplantation the highest leachate N concentration was obtained from I_1T_1 and I_2T_1 treatment combinations and the highest P concentration was observed in I_1T_2 (continuous flooded + 50% NPKSZn+ 5 ton cowdung ha^{-1}) treatment combinations. In the sample of 20 days after transplantation, the highest K concentration (2.02 ppm) was found from the I_2T_3 treatment combination where 50% NPKSZn plus 5 ton compost ha^{-1} with saturated irrigation treatment were applied which was statistically similar to I_2T_4 treatment combination. At 40 days after transplantation, the leachate P concentration highly decreased and the highest concentration of 0.047 ppm was found in I_1T_4 (continuous flooded + 50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment combination. At 40 days after transplantation, the leachate K concentration decreased slightly in inorganic plus organic fertilizer applied treatment and the highest K concentration of 1.39 ppm was obtained from I_2T_3 treatment combination.

The plant height, panicle length and thousand grain weight were not significantly influenced by irrigation treatments but higher plant height and panicle lengths were found in the continuous flooded irrigation treatment. The filled grains $panicle^{-1}$, grain yield and straw yields were significantly influenced by irrigation treatments. The higher number of filled grains panicle^{-1} was found in continuous flooded irrigation treatment. The highest T. aman grain and straw yield was obtained from continuous flooded irrigation. The plant height, panicle lengths, filled grains panicle^{-1}, grain and straw yields were significantly influenced by fertilizer treatments. The T_2 treatment gave the highest plant height and panicle length which was statistically similar to all other treatments except control. The highest number of filled grains/panicle was noticed in the T_3 treatment which was statistically comparable to T_2 treatment and lowest number was found in T_0 treatment. The highest grain yield of 83.65g core^{-1} was obtained from T_1 treatment and the next highest grain yield was found in T_4 treatment and lowest from control treatment. Similarly, the highest straw yield was found in T_1 treatment which was statistically similar to T_4 treatment. The yield parameter and yields were not significantly affected by the interaction of irrigation and fertilizer treatments. The straw yield over the treatment combination varied from 23.27 to 96.80 g core^{-1} and highest T. aman straw yield was obtained in the I_1T_1 treatment combination and lowest in I_2T_0 treatment combination.

5.2 (Experiment 2) Integrated use of organic and inorganic fertilizer on nutrient in pore water, yield contributing character and yield of rice under traditional and saturated irrigation condition

A field experiment involving 2 irrigations and 8 fertilizers were applied in the rice field and fallow area of installed PVC core during January 2014-June 2014, with Boro grown season in sequence, to examine the effect of added fertilizer and manure on rice culture and without rice culture**.** The experiment was laid out in split plot design with a distribution of irrigation to the main plots and fertilizers to the sub plots having 3 replications. The treatment were T_0 = Control, $T_1 = N_{120}P_{25}K_{60}S_{20}Zn_2$ (Recommended dose of fertilizer), T_2 = 50% NPKSZn + 5 ton cowdung ha^{-} ,T_3 = 70% NPKSZn + 3 ton cowdung 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}, T_7 = 70% NPKSZn + 2.1 ton poultry manure ha^{-1}.

The number of effective tillers hill^{-1}, non-effective tillers hill^{-1}, plant height, filled grains panicle^{-1}, grain and straw yields were not significantly affected by irrigation. The higher numbers of effective tillers/hill was found in continuous flooded condition than saturated one but the higher numbers of non effective tiller and filled grain/panicle were found in saturated condition than continuous flooded one. The higher numbers of panicle length were found in continuous flooded condition than saturated condition. The higher grain (7.50 t ha^{-1}) and straw yields (7.30 t ha^{-1}) were obtained in continuous flooded irrigation in comparison to saturated irrigation (Grain yield: 7.25 t ha^{-1}, Straw yield: 7.09 t ha^{-1}). Among the different fertilizer treatments, T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment showed the highest number of effective tillers/hill (15.7) which was statistically similar to T_7, T_5, T_3, T_2 and T_1 treatments. The T_4 (70% NPKSZn + 3 ton cowdung/ha) showed the highest plant height (77.2 cm), which was statistically similar to all other treatments except T_5 and control. The highest number of filled grains/panicle (103.5) was found in T_6 treatment which was statistically and closely similar to T_7, T_5, T_2 and T_3 treatments. Similarly, the highest panicle length was obtained in T_7 treatment and the control (T_0) treatment gave the lowest number of effective tillers/hill, plant height, panicle length and filled grains $panicle^{-1}$.

The application of fertilizers and manure had a positive and significant effect on the grain and straw yield of boro rice (Table 4.2.2). Among the different doses of fertilizers, T_5 (70% NPKSZn + 3 ton compost/ha) showed the highest grain yield (7.78 t ha^{-1}) which was closely similar to T_4, T_6 and T_7 treatments and the lowest grain yield (5.39 t ha^{-1}) was observed with T_0 (control) treatment. Similarly, the highest straw yield (7.90 t ha^{-1}) was obtained in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment which was closely similar to T_2, T_5, and T_7 treatments and the lowest straw yield was obtained in T_0 treatment.

The number of effective tillers/hill and plant height were significantly influenced by combined effects of irrigation and fertilizer. The highest number of effective tillers/hill was found in I_1T_1 (50% inorganic + 5 ton cowdung/ha) treatment combination which was closely similar to I_1T_3, I_1T_6, I_1T_7, I_2T_1, I_2T_6 and I_2T_7 treatment combinations. The highest plant height (80.7) was recorded in I_1T_3 treatment combination which was closely similar to I_1T_6, I_2T_1 and I_2T_7 treatment combinations. The combined effect of different doses of fertilizer and irrigation on the grain yield of boro rice was not significantly different. The highest grain yield of boro rice (7.79 t ha^{-1}) was recorded with the treatment combination I_2T_7 (saturated condition + 70% inorganic fertilizer and 2.1 ton PM/ha) which was closely similar to I_1T_2 (7.72 t ha^{-1}), I_1T_4 (7.76 t ha^{-1}), I_1T_5 (7.79 t ha^{-1}), I_1T_7 (7.71 t ha^{-1}), I_2T_5 (7.77 t ha^{-1}) and I_2T_6 (7.78 t ha^{-1}) treatment combinations and the lowest grain yield (4.97 t ha^{-1}) was found in I_2T_0 (saturated condition + control treatment) treatment combination. The straw yield was not significantly influenced with the interaction of irrigation and fertilizer. The highest straw yield of rice (7.96 t ha^{-1}) was recorded with the treatment combination I_1T_5 (continuous flooded + 50% NPKSZn + 3.5 ton compost/ha) which was similar to I_1T_5, I_1T_7, I_2T_6 and I_2T_7 treatment combinations.

The pore-water N, P, K concentrations were not significantly influenced by irrigation treatments. The pore-water N, P and K concentrations were influenced by different fertilizer treatments. Similar N and P concentrations were found in the I_1 (continuous flooded condition) and I_2 (saturated condition) treatments. The pore-water N concentrations significantly increased in the treatments where fertilizer and manure were applied. Almost similar N concentrations were found in all the treatments except control. Among the fertilizer treatments, the N concentration at 20 days after transplantation varied from 11.80 ppm in T_0 treatment to 17.53 ppm in T_2 (50% NPKSZn + 5 ton cowdung/ha) treatment. At 40 days after transplantation the highest level of available N (15.57 ppm) concentration was obtained from T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure/ha was used which was statistically similar to all other treatments except T_0. The pore water N concentration decreased more in the inorganic fertilizer treatment (T_1) with increasing time and almost similar and higher pore water N levels were found in the T_7 treatment. There was a positive correlation between pore water N and rice yield.

The pore-water P and K concentrations in the rice root zone area decreased with increasing days after transplantation. At 20, 40 and 60 days after transplantation, the higher pore water P concentrations were found in the T_7 treatment which was statistically similar to T_5 and T_6 treatments. At 20 days after transplantation, the highest K concentration in the pore water of rice root zone area (11.34 ppm) was found in the T_4 treatment which was closely similar to T_2, T_5, T_6 and T_7 treatments, where inorganic plus organic fertilizers were used. Pore-water K concentration decreased with increasing days after transplantation but higher K concentrations were found in the organic plus inorganic treatments. At 40 days after transplantation the highest K concentration was observed in T_6 treatment which was statistically comparable to T_1, T_3, T_4, T_5 and T_7 treatments. At 60 days after transplantation the highest K concentration was observed in T_4 treatment which was statistically similar to $T_{3,}$ T_6 and T_7 treatments. Treatment T_2 and T_5 showed almost similar results of pore water K concentration at 60 days after transplantation.

The combined effects of different levels of fertilizer and irrigation on the rice root zone pore-water N, P and K concentrations were significantly different in the samples of different dates (Table 4.2.3). The almost similar pore-water N concentrations were found in the samples of saturated and continuous flooded condition. The highest concentration of 1.84 ppm was found in the sample of 20 days after transplantation from I_1T_7 treatment combination and lowest in I_2T_0 treatment combinations. Similarly, the highest P concentration of 0.69 ppm was found in the sample of 40 days after transplantation from I_1T_6 treatment combination and lowest in I_1T_0 treatment combination. There was a positive correlation between pore water P concentration and yield of rice. The highest pore-water K concentration of 12.47, 5.67 and 4.67 ppm were found at 20, 40 and 60 days after transplantation in the same treatment combination of I_2T_4 (saturated condition + 50% inorganic and 5 ton compost/ha) treatment combinations and lowest concentration was found in I_2T_0 treatment combinations. Higher level of root zone pore water K concentrations and yields were found in the treatment combinations of I_1T_4, I_2T_4 and I_2T_7 due to application of water hyacinth compost and poultry manure in combination of inorganic fertilizer application.

The pore-water N, P and K concentrations were influenced by different irrigation management in the rice root zone area and root free area. The almost similar concentrations of pore-water N and P were found in the rice root zone area (outside the core) and without rice root zone (into the core) during flowering stage of boro rice. In the root zone area, the higher pore-water P (1.01 ppm) and K (3.42 ppm) concentrations were found in the continuous flooded condition in comparison to saturated condition (0.80 ppm P, 2.54 ppm K). The higher pore-water K concentrations were found into the core where plant root was absent. The fallow area (into the core) contained higher concentration of pore water K at flowering stage of rice and it proves that higher levels of applied K stay in pore-water for a long duration in the surface soil. The higher levels of pore-water K concentrations were found inside the core where crop was not grown, and applied K remained in the pore water in soluble form.

The almost similar pore water N and P concentrations were found in the root zone and root free areas during flowering stage of rice with different fertilizer treatments. The higher concentrations of N and P were found in the fertilizer treatments where fertilizer and manures were used. The pore water N concentrations varied in outside (13.90-18.20 ppm) and inside the core (12.33-17.70 ppm). The highest concentration of P (1.39 ppm) was found in the T_4 treatment where 50% NPKSZn + 5 ton compost/ha was used inside the core. The pore water P concentration varied in outside the core (0.43-1.26) and inside the core (0.45-1.39). The pore water K concentration varied in outside the core (2.00-3.50) and inside the core (9.01-11.54). The higher K concentrations were found in the pore-water of fallow area (into the core) where crop root was absent. The higher pore water concentrations inside the core indicated the presence of higher concentration of applied K in the solution due to absence of crop. The presence of higher levels K into the core soil at flowering stage indicated that applied K can stay longer time in the soil solution.

The combined effect of fertilizer and irrigation did not affect the pore-water N concentration of root zone and fallow areas during flowering stage of boro rice. Pore water N concentration varied from 13.47 to 20.07 ppm in the pore water of outside the core (root zone area) and 12.12 to 19.53 ppm) inside the core (fallow area). In the pore-water of root zone area, the highest P concentration of 1.70 ppm was found in the I_2T_5 treatment. In the pore-water of root free area, the highest P concentration of 2.43 ppm was found in the I_2T_6 treatment combination. Lower K concentration was found in the root zone area in comparison to fallow area (into the core). In the fallow area, higher and significantly different K concentrations were found and the highest K concentration of 14.37 ppm was found in the I_1T_1 treatment combination.

The pH of post experiment soils increased more where fertilizers were applied in combination with poultry manure. The level of OM, N, P and K increased in the root zone and root free soil where fertilizer and manure were applied. The higher levels of P and K concentrations were found in the core soil than root zone soil. The post experiment soils of rice root zone area and root free area were significantly influenced by irrigation and fertilizer application.

5.3 (Experiment 3) Integrated use of fertilizer and manure on rice yield, soil fertility and nutrient availability under different irrigation management system in rice – rice cropping pattern

The field experiment was conducted at Sher-e-Bangla Agricultural University Farm during July 2013 to June 2014. The fertilizer treatments were used in this experiment based on latest BARC fertilizer recommendation guide. Three types of organic manure (cow dung, compost and poultry manure) was used in this experiment in combination of inorganic fertilizers. The experiment was laid out in split plot design with a distribution of irrigation to the main plots and fertilizers to the sub plots having 3 replications. The treatment were T_0 = Control, $T_1 = N_{120}P_{25}K_{60}S_{20}Zn_2$ (Recommended dose of fertilizer), T_2 = 50% NPKSZn + 5 ton cowdung $ha^{-}1$, T_3 = 70% NPKSZn + 3 ton cowdung 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}, T_7 =70% NPKSZn + 2.1 ton poultry manure ha^{-1}.

The yield and yield parameters of T. aman rice were not significantly influenced by irrigation but significantly influenced by fertilizer and manure application (Table 4.3.1). Different fertilizer and manure treatments showed significant variations in respect of grain and straw yields of T. aman rice (Table 4.3.1). The application of fertilizers and manure had a positive effect on the grain and straw yields of T. aman rice. The highest straw yield (6.26 t ha^{-1}) was obtained in residual and renewal effect of T_5 (70% NPKS + 3 ton compost ha^{-1}) treatment which was statistically similar to all other treatments except T_0 treatment. The lowest straw yield was obtained in T_0 treatment.

The highest grain yield (4.48 t ha^{-1}) was observed in the T_2 treatment where 50% NPKS + 5 ton cowdung ha^{-1} was used which was statistically similar to all other treatment except T_0 (control). The lowest grain yield (3.79 t ha^{-1}) was observed with T_0 where no fertilizer was applied. The grain and straw yields of T. aman rice were significantly influenced by irrigation and fertilizer treatments. The highest straw yield (7.21t ha^{-1}) was found in I_1T_5 treatment combination which was statistically similar to I_1T_7, I_2T_1, I_2T_2 and I_2T_3 treatment combinations. The highest grain yield of 5.35 t ha^{-1} was recorded in I_2T_2 treatment combination which was statistically comparable to I_1T_5, I_1T_7, I_2T_1, I_2T_3 and I_3T_4 treatment combination.

The number of effective tillers $hill^{-1}$, plant height, number of filled grains $panicle^{-1}$ and grain yields of T. aman rice were not significantly influenced by different levels of irrigation management. The highest grain yield (7.11 t ha^{-1}) was found in I_1 (continuous flooded) treatment and the lowest (6.87 t ha^{-1}) in alternate wetting and drying (I_3). The straw yield was significantly influenced by irrigation and highest straw yield (7.51 t ha^{-1}) was obtained in continuous flooded condition.

The different fertilizers and manures significantly influenced yield parameters of Boro rice (Table 4.3.4). The highest number of effective tillers/hill (14.4) was found in T_1 (100% NPKSZn) treatment and higher plant height, panicle lengths were found in organic plus inorganic fertilizer treatments. Different fertilizer and manure treatments showed significant variations in the grain and straw yields. The application of fertilizers and manure had a positive effect on the grain and straw yield of boro rice. The highest straw yield (7.78 t ha^{-1}) was obtained in T_1 (Recommended dose of chemical fertilizer) treatment which was statistically similar to all other treatments except control. The lowest straw yield was obtained in T_0 treatment. The highest grain yield (7.70 t ha^{-1}) was observed in the T_1 treatment where

100% recommended dose of fertilizer was used which was closely similar with the T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatment. The lowest grain yield (5.02 t ha^{-1}) was observed with T_0 treatment where no fertilizer was applied.

The highest straw yield (8.26 t ha^{-1}) was obtained from I_1T_3 (continuous flooded condition + 70% NPKSZn + 3 ton cowdung/ha) treatment combination which was similar to I_1T_7 and I_1T_2 treatment combination. The highest grain yield of rice (7.94 t ha^{-1}) was recorded with the treatment combination I_1T_7 (continuous flooded + 70% NPKSZn + 2.1 ton poultry manure/ha) which was statistically similar to I_2T_7, I_3T_6 and I_3T_7 treatment combination. On the other hand, the lowest grain yield (5.26 t ha^{-1}) was found in I_2T_0 (continuous flooded condition + control treatment) treatment combination.

The application of manure and fertilizer in the boro seasons and previous application in rice cropping influenced the OM content in soil. The lower level of OM matter was found in the post- experiment soils of T_0 (control) and T_1 (RDCF) treatments. The increase of OM level was almost similar in all the treatment where organic plus inorganic fertilizer were used. Similarly, higher levels of available P were found in the T_2-T_7 treatments where organic plus inorganic fertilizers were used. The highest P concentration was found in the T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure/ha used and that was statistically similar to $T_{6,}$ T_5 and T_2 treatments. The levels of soil N and K concentrations were increased more where inorganic and organic fertilizers were used. The highest K concentration was found in T_5 treatment where 70% inorganic fertilizer and 3 ton/ha water hyacinth compost were used which was statistically similar to all the treatments except control. The pH of post-harvest soils increased in T_6 and T_7 treatments where poultry manure was applied in combination with fertilizer.

CONCLUSION

The leachate N, P and K concentrations varied with irrigation, fertilizer, manure and time of leachate sample collection. The leachate P concentrations decreased rapidly with increasing days after transplantation of Boro and T. Amanrice. Higher leachate K concentrations were found in the saturated irrigation than the leachate samples of continuous flooded irrigation. Higher N and K leaching were found in T_4 (50% poultry manure plus 50% inorganic fertilizer) and T_1 (Recommended dose of fertilizer) treatments and higher yields were obtained in both the treatments. Higher yields of Boro and T.Aman rice were found in continuous flooded irrigation which was significantly different from saturated irrigation treatment. The post-experiment soil chemical properties were affected by irrigation and fertilizer treatments and higher pH was found in the soils (0-15 cm) of saturated irrigation. Among the fertilizer treatments, higher pH, available P were obtained in the T_4 treatment and the level of OM increased where manure plus inorganic fertilizers were used. Higher available K concentrations were obtained in the soils where fertilizers were applied with continuous flooded irrigation.

The growth and yield of rice crops were not significantly affected by irrigation in both field experiment but higher yields were obtained in continuous flooded irrigation in comparison to other irrigation treatments. The effect of residual and renewal added of fertilizer and manure influenced the pore-water nutrient availability, rice yield and the fertility of post-harvest soils. The higher grain yields were obtained in inorganic plus organic treatments. The higher grain yield was obtained from T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure/ha was added. The poultry manure performed better compared to compost and cowdung, for increasing the yield of Boro and T. Aman rice. The concentration of available N, P, K and S in the pore-water varied with irrigation, fertilizer, manure, cropped and without cropped area and time of pore-water collection. The higher concentrations of N, P and K were found in the pore-water of T_6 and T_7 treatments where poultry manure plus inorganic fertilizers were used and higher yields were also obtained. There was a positive correlation between pore-water nutrient concentration and yield of rice. Pore-water P concentration decreased with increasing days after transplantation. Higher concentrations of pore-water K were found into the core (fallow area) than rice root zone area (outside) during the cropping season. Higher soil fertility improvement was found in the post-experiment soils of first field experiment than second field experiment because manure was applied in both boro and T. Aman season in the first experiment. In first experiment, the higher level of organic matter (1.60%) was found in the T_2 treatment (50% NPKSZn + 5 ton cowdung/ha) which was closely similar to other organic plus inorganic treatments and it was 1.20% in T_1 (RDCF) treatment. The level of soil N, P and K concentration increased where manure plus inorganic fertilizers were used. The treatment wise increase of OM levels was similar in the soils of rice field and fallow area of the core. Higher levels of P and K increased and retained in the core soil (0-15 cm) where plant was absent. The core soils K concentration increased around 2 fold compared to the soils of post-experiment soils of outside the core and this information indicate that applied K retained long duration in available form. The application of poultry manure increased the pH of the soil. The higher yields of Boro and T. Aman rice were obtained in 2nd field experiment where 70% inorganic fertilizers plus 30% nutrient from poultry manure or cowdung were applied. The higher pH levels were obtained in the soils where inorganic fertilizer and poultry manure were applied. The level of organic matter, nitrogen and available P significantly increased in the treatments where fertilizer plus manure were applied.

REFERENCES

REFERENCE

Aga, F. A., Singh, J. K., Singh, D. K. and Peer, F. A. (2004).Effect of different levels of compost on growth and yield of rice. *Environ. Ecol*. **22**(2): 353-356.

Ali, M.E., Islam, M. R. and Jahiruddin, M. (2009). Effect of integrated use of organic manures with chemical fertilizers in the rice-rice cropping system and its impact on soil health. *Bangladesh J. Agril.* Res. **34**(1): 41-90.

Ali, M. R., Rahman, M. S.,Mannan, M. A.,Hossain,M. M.and Kadir, M.(2003). Balanced fertilization with inorganic fertilizers in Mustard-Boro-T. Aman cropping pattern. *Bangladesh J. Prog. Sci. T*ech. **1**(1): 33-37.

Anonymous.(1997). Fertilizer Recommendation Guide, Bangladesh Agricultural Research Bangladesh Agril. Res. Inst., Joydebpur, Gazipur, Bangladesh. pp. 249-253. *Bangladesh J. Prog. Sci. Tech***. 1**(1): 33-37.

Aulakh, M. S. (1996). Nitrogen losses and fertilizer N use efficiency in irrigated porous soils. *Nut Cyc Agroeco*, ***47***(3): 197-212.

BARI (Bangladesh Agricultural Research Institute). (2000). Annual Report for 1999-2000. BARI, Gazipur, Bangladesh. pp. 111-253.

BBS. (2014) .Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistices (BBS). Statistical Division, Ministry of Planning Govt. of Peoples Republic of Bangladesh.Dhaka.pp 71.

Beinroth, F. H., Eswaran, H., and Reich, P. F. (2001). Land Quality and Food Security in Asia. *Response to land degradation*, 83-97.

Bhuiya M. R. and Akanda,M. S.(1982). Effect of different sources of organic materials alone and in combination with two fertilizer levels on growth parameters and composition of rice. *Bangladesh J. Agril*. **7**(3-4): 32-39.

Bouyoucos, G. J. (1926). Hydrometer method improved for making particle size analysis of soils.*Agron. J*. **54**: 4661-4665.

Cahn, M. D.Bouldin, D. R. and Cravo, M. S. (1992). Nitrate sorption in the profile of an acid soil. *Plant Soil* **143**: 179–183.

Cahn, M. D.Bouldin, D. R.Cravo, M. S. and Bowen, W. T.(1993).Cation and nitrate leaching in anoxisol of the Brazilian Amazon. *Agron. J*.**8**5: 334–340.

Channbasavana, A. S. and Biradar, D. P. (2001).Response of irrigated rice to the application of poultry manure and inorganic fertilizers N, P and K in Karnataka, India. *Int. Rice Res. Newsl*. **26**(2): 64-65.

Channabasavanna, A. S. (2003). Efficient utilization of poultry manure with inorganic fertilizer in wet land rice.*J. Maharashtra Agric. Univer*. **27**(3): 237-238.

Chittra, L. and Janaki, P. (1999).Impact of various organic sources on K uptake and yield of rice Thambirabarani river tract of Tamil Nadu. *Madrass Agric. J*.**86** (1-3): 46-48

Daniela, R. C., Mark, E. L. and Bruce, A. L. (2016).Rice yields and water use under alternate wetting and dryingirrigation: A meta-analysis.Department of Plant Sciences, University of California − Davis, 387 North Quad, Davis, CA, 95616, USA.

Dao, T. H. and Cavegelli, M. A. (2003). Mineralization carbon, nitrogen and water extractable phosphorous release from composted manure and manure amended soils. *Agron. J*.**95**: 405-413.

Davarynejad, G. H., Haghnia, G. H. and Lakzian, A. (2004).Effect of municipal compost in combination with chemical fertilizers and manure on growth and yield of rice. *Agril. Sci. Tech*. **18**(1): 101-108.

Ebrahim, A., Tarighi, F., Moradi, M. and Bozorgi, H. R. (2011). Evaluation effect of different nitrogen fertilization rates under irrigation management in rice farming. *World Appl. Sci. J*. **13**(5): 1248-1252.

Elsharaeay, M. A. O., Aziz, M. A., and Ali, K. M. (2003).Effect of the application of plant residues composts on some soil properties and yield of wheat and corn plants.*Egyptian J. Soil Sci*. **43**(3): 421-4

Entry, J. A. and Sojka, R. E. (2007).Matrix based fertilizers reduce nitrogen and phosphorus leaching in three soils.*J. Environ.Manag.* **87**(3)**:**364-372.

FAO and UNDP.(1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2, Agro-eco.Reg. Bangladesh. pp. 472-496.

Farid, A. T. D., Miah, M. A. M. andKarim, Z. (1998). Innovative residue management in a typical rice soil of Bangladesh.*Thai. J. Agril. Sci*. **31**(3): 360-368.

Fokhrul, M. I. and Haque, M. F.(1998b). Balanced fertilization with inorganic fertilizers in fertilization with inorganic fertilizers in Mustard-Boro-T. Aman cropping pattern. fertilizers alone and in combination with cowdung on growth yield of potato. *Agril. Sci.* **22**(1):21-29.

FRG Fertilizer Recommendation Guide.(1997). Bangladesh Agricultural Research Council. NARS System.BARC MOA.Council, Farmgate, Dhaka.p. 47.

Gaihre, Y. K, Singh, U., Islam, S. M. M., Huda, A., Islam, M. R. andSatter, M. A. (2015). Impacts of urea deep placement on nitrous oxide and nitric oxide emissions from rice fields in Bangladesh. Geoderma. 2015;259:370–9. doi: 10.1016/j.geoderma.2015.06.001.WOS:000360867800039.

Gani, A., Rahman, A., Dahono, R. and Hengsdijk, H. (2002). Synopsis of water management experiments in Indonesia. *Water Wise Rice Production*, **IRRI**: 29-38.

Gomez, K. A. and Gomez, A. A. (1984).Statistical procedures for Agricultural Research.Jhon Wiley and Sons, New York.

Goyal, S., Chander, K.,Mundra, M. C. and Kapoor, K. K.(1999). Influence of inorganic fertilizers and organic amendments on soil organic matter and soil micobial properties under tropical conditions. *Biol. Fertil. Soils* **29**:196–200.

HDRA (Henry Doubleday Research Association). (1999). Researching the use of compost in agriculture report on work for 1998. HDRA consultants Ltd., Conventry UK.p. 137.

He, Y., Lehndorff, E., Amelung, W., Wassmann, R., Alberto, M.C., Unold, G. V.,and Siemens, J (2015). Drainage and leaching losses of nitrogen and dissolved organic carbon after introducing maize into a continuous paddy-rice crop rotation.*Agric. Ecosys.and Environ.***249**: 91–100.http://dx.doi.org/10.1016/j.agee.2017.08.021.

Hossain M. A., Salahuddin, A. B. M., Roy, S. K., Nasreen, S. and Ali, M. A.(1995). Effect of Green manuring on the growth and yield of transplanted aman rice. *Bangaldesh J. Agril.Sci*. **22**(1):21-29.

Hunter, A. H. (1984). Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Islam, M. A. F., Khan, M. A., Bari, A. F., Hosain, M. T. and Sabikunnaher, M. (2013). Effect of Fertilizer and Manure on the Growth, Yield and Grain Nutrient Concentration of Boro Rice (*Oryza sativa L.*) under Different Water Management Practices. *The Agriculturists*, **11**(2): 44-51.

Islam, M. N.,Rahman, M. M., Mlan, M. J. A., Khan,M. H. andBarua, R. (2014).Leaching losses of nitrogen, phosphorus and potassium from the sandy loam soil of old Brahmaputra floodplain (AEZ-9) under continuous standing water condition. ISSN 0258-7122. *Bangladesh J. Agril. Res*. **39**(3): 437-446.

Islam, M. R; Sikder, S.,Bahadur, M. M., Hafiz, M. H. R. (2012).Effect of Different FertilizerManagement on Soil Properties and Yield of Fine Rice Cultivar.J. *Environ. Sci. & Nat.* **5**(1): 239-242, 2012 DOI: http://dx.doi.org/10.3329/jesnr.v5i1.11588.

Islam, S. Z. (2012). Effect of Consecutive Applications of Municipal Solid Waste Compost and Fertilizers on the Growth and Yield of BRRI dhan50. Doctoral dissertation paper presented at the workshop on Intrgrated Nutrient Management for Sustainable Agriculture, held at Soil Resour. Dev. Inst. Dhaka in June 15-17. 2012.

Islam, M. A., Khan, M. A and Rouf, M. A. (2011).Nutrient dynamics in paddy soil under Rice culture mesocosm studies.*J Bangladesh Agril. Univ.***1**5(2*):* 199–205, 2017 doi: 10.3329/jbau.v15i2.35063.

Islam, M. R., Rashid,M. B.,Siddique,A. B. andAfroz,H. (2007). Integrated effects of manures and fertilizers on the yield and nutrient uptake by BRRI dhan49. *J. Bangladesh Agril.Uni*.**12**(1): 67–72, 2014.

Iqbal, M. T. (2010).Nitrogen Leaching from Paddy Field under Different Fertilization Rates. *Malaysian J. Soil Sci*. **1**5: 101- 114.

Jackson, M. L. (1962). Soil Chemical Analysis. Constable and Co. Ltd. London, First Print.

James, A.E. and Sojka, R. E. (2007). Matrix based fertilizers reduce nitrogen and phosphorus leaching in three soils.*J. Environ.Manag*.**83:** 364-372.

Katoh, M., Iwata, A., Shaku, I., Nakajima, Y.,Matsuya, K. and Kimura, M. (2005). Impact of water percolation on nutrient leaching from an irrigated paddy field in Japan. https://doi.org/10.1111/j.1475-2743.2003.tb00319.x.

Keeling, A. A., Mccallum, K. R. and Beckwith, C. P. (2003). Mature green waste compost enhances grown and nitrogen uptake in wheat (*Triticumaestivum*L.) and oilseed rape (*Brassica napus* L.) through the action of water extractable factors. *Biores.Technol*. **90**(2): 127-132.

Kleinman, P. J. A.; Srinivasan, M. S.; Sharpley, A. N. and Gburek, W. J. (2005).Phosphorus leaching through jntact soil columns before and after poultry manure application. *Soil Sci*. **170**(3): 153-166

Kumar, V., and Singh, O. P. (2006). Effect of manures Nitrogen and Zinc fertilization on growth, yield, yield attributes and quality of rice (*Oryza sativa* L.). *Intl. J. Plant Sci.* **1**(2): 311-314.

Lee, J. and Choi, H. L. (2014). The dynamics ofnitrogen derived from a chemical nitrogen Fertilizer with treated swine slurry in paddy soil-plantsystems. PLoS ONE 12(3): e0174747.https://doi.org/10.1371/journal.pone.0174747

Lehmann, J., Jr. Silva, J. P. S., Steiner, C., Nehls, T.,Zech, W. and Glaser, B. (2003). Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments.*Plant Soil*.**249**: 343–357, 2003.

Liu, X., Wang, H., Zhou, J., Hu, F., Zhu, D. and Chen, Z. (2016). Effect of N Fertilization Pattern on Rice Yield, N Use Efficiency and Fertilizer–N Fate in the Yangtze River Basin, China. PLoS ONE 11(11): e0166002. doi:10.1371/journal.pone.0166002

Li, Y., Gao, R., Yang, R., Wei, H., Li, Y., Xiao, H. and Wu, J. (2013). Using a Simple Soil Column Method to Evaluate Soil Phosphorus Leaching Risk. *Clean Soil Air Water.* **41**(11): 1100–1.

Lin, X., Zhu, D. and Xinjunlin.(2011). Effects of water management and organic fertilization with SRI crop practices on hybrid rice performance and rhizosphere dynamics. *Paddy Water Environ.***9**: 33-39.

Mahavisha, K., Reddy, A. S. and Rekha, K. B. (2004).Effect of organic sources of plant nutrients in conjunction with chemical fertilizers on growth, yield and quality of rice.*Res. Crops*.**5**(2/3): 159-161.

Mannan, M. A., Kamal, A. M. A. and Islam, R. (2000).Effect of manure and fertilizer on growth, yield and protein content of transplant aman rice.*Bangladesh J. Train. Dev*. **13**(1-2): 203-210.

Matin, N. H. and Jalali, M. (2013). The effect of waterlogging on electrochemical properties and soluble nutrients in paddy soils. Paddy Water Environ.**15**:443–455.

Mchugh, O. V., Steenhuis, T. S., Barison, J., Fernandes, E. C. M. and Uphoff, N. (2002). Farmer implementation of alternate wet and drying and nonflooded irrigation practicess in the System of Rice Intensification. *Water Wise Rice Production*, **IRRI**: 3-14.

Melgar, S., Mathew, T. and Nair, S. S. (1992).Physical and chemical properties of rice soils as influenced by organic and inorganic sources of nutrients. *Indian J. Agril. Res*. **31**(4): 257-261.

Meng F., Olesen, J.E., Sun, X. and Wu, W. (2014).Inorganic Nitrogen Leaching from Organic and Conventional Rice Production on a Newly Claimed Calciustoll in Central Asia. PLoS ONE **9**(5): e98138. https://doi.org/10.1371/journal.pone.0098138.

Miah, M. A. M., Shah, A. L. and Ishaque, M. (2004).Nutrient management for different rice ecosystem.Proc. of the workshop on modern rice cultivation in Bangladesh. BRRI, Gazipur, Bangladesh.19-21. April.**159**: 179-199.

Miah, M. A. M., Ishaque, M. and Saha, P. K. (2006).Integrated nutrient management for improving soil health and rice production. Proc. of twenty first BRRI-DAE joint workshops on bridging the rice yield gap for food security. BRRI, Gazipur, Bangladesh, 19-21 September, paper **11**: 1-15.

Miah, M. M. A., Gaihre, Y. K., Hunter, G., Singh, U.and Hossain, S. A. (2016). Fertilizer Deep Placement Increases Rice Production: Evidence from Farmers' Fields in Southern *Bangladesh. Agron. J*. **108**(2):805. doi: 10.2134/agronj2015.0170.

Moe, K. K., Win, M., Win, K. K. andYamakawa, T. (2017a). Combined Effect of Organic Manures andInorganic Fertilizers on the Growth andYield of Hybrid Rice (Palethwe-1).*American J. Plant Sci*.**8**: 1022-1042. DOI: 10.4236/ajps.2017.85068 April 21, 2017.

Moe, K., Mg,K.W., Win, K.K. and Yamakawa, T. (2017b). Effects of Combined Application of Inorganic Fertilizer and Organic Manures on Nitrogen Use and Recovery Efficiencies of Hybrid Rice (Palethwe-1). *American J. Plant Sci*.**8**: 1043-1064.

Morshedizad, M., and Leinweber, P. (2015). Leaching of Phosphorus and Cadmium in Soils Amended with Different Bone Chars. *Clean J. Soil Air Water*. DOI: 10.1002/clen.201600635.

Nayak, D. R., Babu, X. and Adhya, T. K. (2007). Long-term application of compost influences mineral biomass and enzyme activities in a tropical AericEndoaquept planted to rice under flooded condition. *Soil Microbiol.Biochem*.**39**(8): 1897-1906.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954).Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Dept. Agric. Circ., p. 929.

Page, A. L., Miller, R. H. and Keeney, D. R. (1982). Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. pp. 403-430.

Pathak, B.K., Kazama, F. and Toshiaki, I. (2001).Monitoring of Nitrogen Leaching from a Tropical Paddy in Thailand.Agric. Eng. Int.: the CIGR J. Sci. Res. Dev.Pp 45.

Peng,S.Z., Yang, S.H.,Xu,J.Z.,Luo,Y.F. andHou,H.J. (2008). Nitrogen and phosphorus leaching losses from paddy fields with different water and nitrogen managements. tateKey Laboratory of Hydrology-Water Resources and Hydraulic Engineering, HohaiUniversity, Nanjing 210098, *Paddy Water Environ*.**9**:333–342. DOI 10.1007/s10333-010-0246-y.

Qinghua, S., Zeng, X., Li, M., Tan, X. and Xu, F. (2002).Effects of different water management practices on rice growth.*Water Wise Rice Production*, **IRRI**. 3-14.

Rahman, M. S., Islam, M. R., Rahman, M. M. and Hossain, M. I. (2009).Effect of cowdung, poultry manure and urea-N on the yield and nutrient uptake of BRRI dhan29.*Bangladesh Res. Pub. J*. **2**: 552-558.

Reddy, B. G. M., Pattar, P. S. and Kuchanur, P. H. (2005). Response of rice to poultry manure and graded levels of NPK under irrigated conditions. Oryza. **42**(2): 109-111.

Rejesus, R. M., Mutuc, M. E. M., Yasar, M., Lapitan, A. V., Palis, F. G., & Chi, T. T. N. (2012). Sending Vietnamese rice farmers back to school: further evidence on the impacts of farmer field schools. *Canadian J. Agric. Econ.* **60**(3): 407-426.

Rochette, P., Angers, D. A., Chantigny, M. H., Gasser, M. O., MacDonald, J. DandPelster, D. E. (2013).Ammonia volatilization and nitrogen retention: how deep to incorporate urea? *J. Environ. Qual*. **42**(6):1635–42. doi: 10.2134/jeq2013.05.0192. pmid:25602404.

Rouf, M. A., Khan, M. A.,Mitu, A. S., Rabin, M. H.,Biswas, P.and Masud, M. A. A. (2011). Interaction Effect of Fertilizer andManure on the Growth and Yield of T. Aman Rice in Different Soil.*Int. J. Sci. Res. Pub*. **7**(9): 53.

Saha, P. K., Ishaque , M., Saleque , M. A.,Miah ,M. A. M., Panaullah, G. M and Bhuiyan, N. I.**(**2007).Long-Term Integrated Nutrient Management for Rice-Based Cropping Pattern: Effect on Growth, Yield, Nutrient Uptake, Nutrient Balance Sheet, and Soil Fertility.*J. Com. Soil Sci. Plant An*a.**38**: 73**.**

Saleque, M.A., Abedin,M.J., Bhuiyan, N.I.,Zaman, S.K.and Panaullah, G.M.(2008). Long-term effects of inorganic and organic fertilizer sources on yield and nutrient accumulation of lowland rice. *Soil Sci. Soc. Am. J*.**48**: 1503-1506.

Saitoh, K., Kuroda,T. and Kumano, S. (2001). Effect of organic fertilization and pesticide application on growth and yield of field- grown rice for 10 years. *Japanese J. Sci*. **70**(4): 530-540.

Saleque, M. A., Abedin, M. J., Bhuiyan, N. I., Zaman, S. K. and Panaullah, G. M. (2004).Long-term effects of inorganic and organic fertilizer sources on yield and nutrient accumulation of low land rice. *Field crops Res*. **86**(1): 53-56.

Saleque, M. A.. Nahar, U. A., Islam, A., Pathan, A. B.,Uddin, M. B., Hossain, A. T. M. S. and Meisner, C. A. (2004). Inorganic and organic phosphorus fertilizer effects on the phosphorus fractionation in wetland rice soils. *Soil Sci. Soc. Amer. J*. **68**: 1635-1644

Singh, R., Singh, S. and Prasad, K. (2001).Effect of fertilizer, FYM and row spacing on transplanted rice.*Crop Res*. (Hisar). **22** (2): 296-299.

Singh,Y., Singh, B., Timsina, J. (2005).Crop Residue Management for Nutrient Cycling and Improving Soil Productivity in Rice-Based Cropping Systems in the Tropics. *Adv. Agron.***85**: 269–407.

Sun, L., Gu, L., Peng, X., Liu, Y., Li, X. and Yan, X. (2012). Effects of Nitrogen Fertilizer Application Time on Dry Matter Accumulation and Yield of Chinese Potato Variety KX13. Potato Res. **55**(3):303–13. doi: 10.1007/s11540-012-9220-y.

Tamaki, M., Itani, T. and Nakanu, H. (2002).Effect of continuous organic farming on the growth and yield of rice. *Japanese J. Crop Sci*. **71**(4): 439-445.

Tan, X., Shao, D., Liu, H., Yang, F., Xiao, C. and Yang, H. (2007). Effects of alternate wetting and drying irrigation on percolationand nitrogen leaching in paddy fields. State Key Laboratory of Water Resources and HydropowerEngineering Science, Wuhan University, Wuhan, China. *Paddy Water Environ.***11**:381–395DOI 10.1007/s10333-012-0328-0.

Thakur, A. K., Rath, S., Patil, D. U. and Kumar, A. (2011). Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implications for crop performance. *Paddy Water Environ.***9**: 13-24.

Tripathy,R. K., Pandey, N., Mishra, P. K. and Rajput, R. S. (2004). Branching behavior and production of chickpea as influenced by residual effect of cowdung blended nutrients applied to hybrid rice and direct application of nutrients to chickpea under hybrid rice-chickpea cropping system.

Umanah, E. E., Ekpe, E. O., Ndon, B. A. , Etim, M. E. and Agbogu, M. S. (2003). Effect of poultry manure on growth characteristics, Yield and Yield components of upland rice in South Eastern Nigeria.*J. Sus. Agric. Environ*. **5** (1): 105-110.

Uphoff, N. and Randriamiharisoa, R. (2002).Reducing water use in irrigated rice production with Madagascar System of Rice Intensification.*Water Wise Rice Production*, **IRR**I: 71-88.

Vanaja, M. and Raju, A. S. (2002).Integrated nutrient management performance in rice crop.AbbakasUmanah, E. E., Ekpe, E. O., Ndon, B. A. , Etim, M. E., Agbogu, M. S. (2003). Effect of poultry manure on growth characteristics, Yield and Yield components of upland rice in South Eastern Nigeria.*J. Sus. Agric. Environ*. **5** (1): 105-110.

Vijay Kumar, and Singh, O. P. (2006). Effect of manures Nitrogen and Zinc fertilization on growth, yield, yield attributes and quality of rice (*Oryza sativa* L.). *Intl. J. plant Sci. Muzaffarnagar*.**1**(2): 311-314.

Wang, J., Wang, D.,Zhang, G.,Wang, Y., Wang, C., Teng, Y., Christie, P. (2007). Nitrogen andphosphorus leaching losses from intensively managedpaddy fields with straw retention. *J. Agric. Water Manag*.**141**:66–73.

Yadav, R.,Dwivedi, B.S.,Prasad, K., Tomar,O.K.,Shurpali,N.J. andPandey, P.S. (2013). Yield trends, and changes in soil organic-C and available NPK in a long-term rice–wheat system under integrated use of manures and fertilizers. http://doi.org/10.1016/S0378- 4290(00)00126-X

Yanan, T.,Emteryd, O.,Dianqing, L.and Grip, H. (1980).Effect of organic manure and chemical fertilizer on nitrogen uptake and nitrate leaching in a Eum-orthicanthrosols profile. *Nutrient Cyc. Agroeco*.**48**: 225–229, 1997.

Yang, C., Yang, L., Yang, Y. andOuyang, Z. (2004). Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agric. Water Manag.* **70**(1): 67-81.

Zhang C, Che, Y. P.and Li, Z. P. (2011). Translocation and transformation characteristics of fertilizer nitrogen in paddy soil: a study with simulated soil colunm. *Chinese J. Appl. Ecol*.**22**(12):3236–42.

Zhang, H. C., Cao, Z. H.,Shen, Q.R and Wong, M. H (2000). Effect of phosphate fertilizer Application on phosphorus (P) losses from paddy soils in Taihu Lake Region: I. Effect of phosphate fertilizer rate on P losses from paddy soil. *Chemosphere*.**50**(6): 695-701.

Zhao, L., Wu, L., Wu, M. and Li, Y. (2011). Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with reduced irrigation. *Paddy Water Environ*.**9**: 25-32.

APPENDIX

Appendix I. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from January 2013 to June 2014

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
January, 2013	24.8	14.2	66	6.6	5.8
February, 2013	27.7	16.1	67	27.8	5.5
March, 2013	33.5	21.9	65	64.7	5.6
April, 2013	49.5	27.5	69	165.9	4.8
May, 2013	31.5	19.2	73	34.4	5.1
June, 2013	31.4	19.6	54	11	8.2
July, 2013	33.6	23.6	69	163	6.4
August, 2013	33.2	25.4	72	195	6.3
September, 2013	23	16	45	61	5.3
October, 2013	25	18	55	137	4.7
November, 2013	25.8	16.0	78	5.5	6.8
December, 2013	22.4	13.5	74	4.6	6.3
January, 2014	24.5	12.4	68	4.3	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	31.4	19.6	54	11	8.2
April, 2014	48.2	28.0	68	160.8	4.6
May, 2014	30.9	19.5	71	35.1	5.3
June, 2014	32.5	20.0	55	12	8.1

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212.