

**ADAPTATION OF NERICA RICE IN LATE T-AMAN
SEASON UNDER INTEGRATED NUTRIENT
MANAGEMENT SYSTEM**

MOST. HOSNE ARA HIRA



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

DECEMBER, 2013

**ADAPTATION OF NERICA RICE IN LATE T-AMAN
SEASON UNDER INTEGRATED NUTRIENT
MANAGEMENT SYSTEM**

By

MOST. HOSNE ARA HIRA

Reg. No.: 11-04708

A Thesis

**Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE**

SEMESTER: JULY-DECEMBER, 2013

Approved By:

.....
Supervisor

Prof. Dr. Alok Kumar Paul

Department of Soil Science

Sher-e-Bangla Agricultural University

Dhaka-1207

.....
Co-supervisor

Prof. Most. Afrose Jahan

Department of Soil Science

Sher-e-Bangla Agricultural University

Dhaka-1207

.....
Chairman

Dr. Mohammad Issak

Associate Professor

Department of Soil Science

Sher-e-Bangla Agricultural University, Dhaka-1207



শেৰে বাংলা কৃষি বিশ্ববিদ্যালয়

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh

গবেষণা CERTIFICATE সম্ভাষণ

This is to certify that the thesis entitled " ADAPTATION OF NERICA RICE IN LATE T-AMAN SEASON UNDER INTEGRATED NUTRIENT MANAGEMENT SYSTEM" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) IN SOIL SCIENCE, embodies the results of a piece of bona fide research work carried out by MOST. HOSNE ARA HIRA, Registration No. 11-04708, under my supervision and guidance. No part of this 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:

Dhaka, Bangladesh

(Prof. Dr. Alok Kumar Paul)
Supervisor

ACKNOWLEDGEMENT

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

I feel much pleasure to express my gratitude, sincere appreciation and heartfelt indebtedness to my reverend research supervisor Professor Dr. Alok Kumar Paul, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period.

I also express my gratefulness to respected co-supervisor, Most. Afrose Jahan, Professor and honorable Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for her constant inspiration, valuable suggestions, cordial help, heartiest co-operation, providing all facilities and supports which were needed to completing the study.

I would like to express my sincere gratitude to my respectable teacher Jharna Rani Sarkar, Assistant Professor, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for her valuable advice and providing necessary facilities to conduct the research work.

I would like to express my deepest respect and thanks to all my honorable teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University (SAU) for their valuable suggestions, instructions, cordial help and encouragement.

I am extremely thankful to all M.S. student of July-December/2011 and January-June/2012 semester, all officers and staffs of the Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for their kind support and sincere co-operation during my study.

Finally, I express my deepest sense of gratitude to my beloved parents, brothers, sisters, other family members, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study.

Dhaka, Bangladesh
November, 2013

The Author

ABSTRACT

A field experiment was conducted to assess the effect of integrated nutrient management on the growth and yield of NERICA 10 rice crop at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during late T-Aman season (August-December), 2012. One hundred kg N from urea and Twenty kg N substituted by vermicompost (T₃ Treatment) gave the maximum yield and performed best in yield attributing characters of NERICA 10. The effect of vermicompost along with nitrogenous fertilizer was the most pronounced than that of cowdung or nitrogenous fertilizer alone. Similar effects were also observed on N, P, K, S content and their uptake by NERICA 10. The effect of 100 kg N from urea along with 20 kg N from vermicompost (T₃ Treatment) was statistically identical to 100 kg N from urea with 20 kg N substituted by cowdung (T₄ Treatment), 80 kg N from urea with 40 kg N substituted by vermicompost (T₅ Treatment), 80 kg N from urea with 40 kg N substituted by cowdung (T₆ Treatment), 60 kg N from urea with 60 kg N substituted by vermicompost (T₇ Treatment), 40 kg N from urea with 80 kg N substituted by vermicompost (T₉ Treatment) and 100% N substituted by equal portion of vermicompost and cowdung (T₁₁ Treatment). The effect of 100 kg N from urea along with 20 kg N from vermicompost (T₃ Treatment) was dissimilar with Control (T₁ Treatment), 100% recommended N i.e.120 kg nitrogen / ha (T₂ Treatment), 60 kg N from urea with 60 kg N substituted by cowdung (T₈ Treatment) and 40 kg N from urea with 80 kg N substituted by cowdung (T₁₀ Treatment). In post harvest soils, the contents of total nitrogen, available phosphorus, exchangeable potassium and available sulphur increased due to application of cowdung and vermicompost compared to initial soil. The overall results indicate that 100 kg N from urea along with 20 kg N from vermicompost was the best treatment in producing higher rice yield with sustenance of soil fertility.

CONTENTS

CHAPTER	TITLE	PAGES
	ACKNOWLEDGEMENT	i
	ABSTRACT	ii
	CONTENTS	iii
	LIST OF TABLES	v
	LIST OF FIGURES	vi
CHAPTER 1	INTRODUCTION	1
CHAPTER 2	REVIEW OF LITERATURE	4
CHAPTER 3	MATERIALS AND METHODS	25
3.1	Experimental details of site	25
3.1.1	Soil	25
3.1.2	Crop	25
3.1.3	Land preparation	25
3.1.4	Experimental design	28
3.1.5	Layout of the experiment	28
3.1.6	Seed sowing	28
3.1.7	Collection and preparation of initial soil sample	28
3.1.8	Treatments	30
3.1.9	Application of fertilizers	30
3.1.10	Intercultural operations	31
3.1.11	Plant sampling at harvest	31
3.1.12	Harvesting	31
3.1.13	Data collection	31
3.1.13.1	Plant height (cm)	32
3.1.13.2	Number of tillers hill ⁻¹	32
3.1.13.3	Panicle length	32
3.1.13.4	Filled and unfilled grains panicle ⁻¹	32
3.1.13.5	1000-grain weight	32
3.1.13.6	Grain and straw yields	32
3.1.14	Chemical analysis of soil samples	32
3.1.14.1	Particle size analysis	32
3.1.14.2	Soil pH	33
3.1.14.3	Organic carbon	33
3.1.14.4	Total nitrogen	33
3.1.14.5	Available phosphorus	33
3.1.14.6	Exchangeable potassium	33
3.1.14.7	Available sulphur	34
3.1.15	Chemical analysis of plant samples	34
3.1.15.1	Preparation of plant samples	34
3.1.15.2	Digestion of plant samples with sulphuric acid	34
3.1.15.3	Digestion of plant samples with nitric-perchloric acid mixture	34
3.1.16	Statistical analysis	35

CHAPTER	TITLE	PAGES
CHAPTER 4	RESULT AND DISCUSSION	36
4.1	Growth and yield components	36
4.1.1	Plant height	36
4.1.2	Panicle length	37
4.1.3	Effective tillers hill ⁻¹	38
4.1.4	Filled grains panicle ⁻¹	39
4.1.5	Unfilled grains panicle ⁻¹	40
4.1.6	1000-grain weight	41
4.2	Yields	43
4.2.1	Grain yield	43
4.2.2	Straw yield	43
4.3	Nutrient content in grain and straw	46
4.3.1	Nitrogen content	46
4.3.2	Phosphorus content	47
4.3.3	Potassium content	47
4.3.4	Sulphur content	48
4.4	Nutrient uptake	50
4.4.1	Nitrogen uptake	50
4.4.2	Phosphorus uptake	50
4.4.3	Potassium uptake	51
4.4.4	Sulphur uptake	52
4.5	Nutrient content in post harvest soil	54
4.5.1	Total nitrogen	54
4.5.2	Available phosphorus	54
4.5.3	Exchangeable potassium	54
4.5.4	Available sulphur	54
CHAPTER 5	SUMMARY AND CONCLUSION	56
	REFERENCES	59
	APPENDICES	75

LIST OF TABLES

TABLE	TITLE	PAGE
1	Morphological characteristics of experimental field	27
2	Physical and chemical properties of the initial soil samples	27
3	Nitrogen percentage in different elements in the experiment	30
4	Effect of Integrated Nutrient Management on plant height, panicle length, effective tillers hill ⁻¹ , filled grains panicle ⁻¹ , unfilled grains panicle ⁻¹ and 1000-grain weight of NERICA 10	42
5	Effect of Integrated Nutrient Management on the grain and straw yields (t ha ⁻¹) of NERICA 10	45
6	Effect of Integrated Nutrient Management on N, P, K and S content (%) of NERICA 10	49
7	Effect of Integrated Nutrient Management on N, P, K and S uptake (kg ha ⁻¹) of NERICA 10	53
8	Effect of Integrated Nutrient Management on N, P, K and S content in post harvest soil of NERICA 10	55

LIST OF FIGURES

FIGURE	TITLE	PAGE
1	Map showing the experimental site under study	26
2	Layout of experimental field	29
3	Effect of Integrated Nutrient Management on percent increase plant height over control of NERICA 10	37
4	Effect of Integrated Nutrient Management on percent increase panicle length over control of NERICA 10	38
5	Effect of Integrated Nutrient Management on percent increase number of effective tillers hill ⁻¹ over control of NERICA 10	39
6	Effect of Integrated Nutrient Management on percent increase number of filled grains panicle ⁻¹ over control of NERICA 10	40
7	Effect of Integrated Nutrient Management on percent increase number of unfilled grains panicle ⁻¹ over control of NERICA 10	41
8	Effect of Integrated Nutrient Management on percent increase grain yield (t ha ⁻¹) over control of NERICA 10	44
9	Effect of Integrated Nutrient Management on percent increase straw yield (t ha ⁻¹) over control of NERICA 10	44

CHAPTER I

INTRODUCTION

Rice has been grown in Ganges delta of Bangladesh for thousands of years and the country was once home to 4,000 varieties of the grain, but it is unable to produce enough for its own needs, even without one of its frequent natural disasters. Bangladeshi officials say NERICA, the New Rice from Africa, developed around a decade ago by an institute in Ivory Coast, could boost the food security in Bangladesh as global weather patterns make that task more challenging. The country initially trialed NERICA, which is drought-resistant and fast-growing, in 2009 and after better-than-expected field results last year a nationwide trial has been rolled out involving 1,500 farmers.

In Late T-Aman season, sufficient rainfall is not available for rice cultivation. Maximum high-yielding rice varieties require 140 to 160 days to fulfill their life cycle.

NERICA is a drought tolerant short duration crop usually requires 90-100 days. So it can be cultivated in late T-Aman season and can save irrigation cost as well as time which is a good sign for ensuring food security of the nation.

NERICA, originally intended to raise rice output in African countries, can be harvested in 90 to 100 days, requires limited water, it was designed for Africa's dry lands and is very high-yielding. In contrast, many rice strains now popular with Bangladesh's ten millions of farmers require a large amount of water, forcing farmers, particularly those in the drought-hit north, to invest in irrigation systems and leading to sharp falls in groundwater levels. Moreover, the high-yielding rice varieties currently used in Bangladesh take between 140 and 160 days to harvest, according to the BADC, which provides some 70 percent of the rice and cereal seeds used by local farmers. NERICA's shorter harvest period was what first prompted BADC to turn to the rice strain in hopes that it could solve a key dilemma in Bangladesh.

During dry season especially in the high to medium high land of northern region of Bangladesh, irrigation water scarcity is becoming severe due to lowering of water table resulting from extensive water lifting through deep and shallow tube wells for

Boro rice cultivation. Cultivation of dry HYV rice under such a harsh environment may pave the new way of increasing rice production in Bangladesh. Drought resistant rice cv. NERICA 10 may be the answer to this problem if grown under proper management practices. As NERICA 10 is a new crop in Bangladesh, development of proper fertilizer management strategy is one of the most important agronomic practices for its successful adoption in Bangladesh.

Integrated Nutrient Management (INM) maintains soils as storehouses of plant nutrients that are essential for vegetative growth. INM's goal is to integrate the use of all natural and man-made sources of plant nutrients, so that crop productivity increases in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. INM relies on a number of factors, including appropriate nutrient application and conservation and the transfer of knowledge about INM practices to farmers and researchers.

Integrated nutrient management (INM) implies the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other. It is achieved through efficient management of all nutrient sources. Nutrient sources to a plant growing on a soil include soil minerals and decomposing soil organic matter, mineral and synthetic fertilizers, animal manures and composts, by-products and wastes, plant residue, and biological nitrogen fixation (BNF). Irrigation water and aerial deposition generally are minor nutrient sources. The INM is, however, not a matter of conserving soil nutrient alone, but rather it combines organic and mineral methods of soil fertility management with physical and biological measures of soil and water conservation. It integrates technologies that are site-specific to agronomic and socio-economic conditions to redress nutrient imbalances and organic matter deterioration.

The INM must essentially look into three main challenges: (i) judicious use of mineral fertilizers; (ii) maximize use of organic materials; and (iii) minimize negative environmental impacts. The overall strategy of INM, for determining the yield-based nutrient requirements, involves several steps, for example (i) availability of on-farm and off-farm resources; (ii) yield target based on resource availability; (iii) nutrient requirement to achieve desired yield; (iv) integration of mineral and organic

fertilizers; (v) time and method of fertilizer application; (vi) efficient soil and water conservation measures; and (vii) sustaining physical, chemical, and biological fertility of soils. From an experiment it was found that the hybrid rice Chinese cultivar-Sonarbangla-1 produced a 20% higher rice yield (7.55 t ha^{-1}) than the check variety, BRRI Dhan-29, (6.26 t ha^{-1}) in Bangladesh (Parvez *et al.*, 2003).

The organic manures viz. cowdung and vermicompost may be used as an alternative source of N which increases efficiency of applied N (Saravanan *et al.*, 1987). Integrated use of organic manures with the combination of inorganic fertilizers can contribute to increase N content of rice soil as well as to increase long term productivity and enhancement of ecological sustainability (Gill and Meelu, 1982).

Combined application of cowdung and vermicompost along with chemical nitrogen fertilizer improves soil health and soil productivity but only use of nitrogenous fertilizer for a long period causes deterioration of physical condition and organic matter status and reduces crop yield. When cowdung and vermicompost are applied along with chemical fertilizers for efficient growth of crop, decline in organic carbon is arrested and the gap between potential yield and actual yield is bridged to large extent (Rabindra *et al.*, 2005). Now a days, it is the demand of time to develop an integrated nutrient management program for higher crop yield and improve soil health ultimately increase the crop sustainability. Keeping these facts in mind the following objectives are undertaken:

1. To observe the performance of NERICA 10 rice variety in late T-Aman season of Bangladesh as short duration variety before boro cultivation.
2. To maintain the soil health by adopting Integrated Nutrient Management system in rice cultivation.

CHAPTER II

REVIEW OF LITERATURE

A number of research works relating to the application of organic manures and chemical fertilizers to rice crop have been carried out in different rice growing countries of the world including Bangladesh. A better understanding of the effects of the nutrients supplied from manures and fertilizers on rice will obviously facilitate the development of some agronomic practices for production of other crops. Since review of literature forms a bridge between the past and present research works related to problem, which helps an investigator to draw a satisfactory conclusion, an effort was thus made to present some research works related to the present study in this section. This chapter includes the available information regarding the effect of cowdung and vermicompost along with chemical nitrogenous fertilizers on NERICA 10.

2.1 Effects of chemical fertilizers on the growth and yield of rice

2.1.1 Nitrogenous fertilizers

Atera *et al.* (2011) conducted an experiment on field evaluation of selected NERICA rice cultivars in Western Kenya and reported that the highest plant height (103.8 cm) was obtained from 100 kg N ha⁻¹.

Kamara *et al.* (2011) conducted an experiment on the influence of nitrogen fertilization (0, 30 and 100 kg N ha⁻¹) on yield and yield components of rain-fed low land NERICA rice and reported that nitrogen application influenced number of spikelets panicle⁻¹ significantly by 19 to 22% over the control. In both years, number of spikelets increased with increasing nitrogen rates.

Bahmanyar and Mashaee (2010) found that maximum grain yield (75.46 g pot⁻¹) was found @ 23 kg N ha⁻¹ in Aus rice.

Salahuddin *et al.* (2009) conducted an experiment to study the effect of nitrogen levels and plant spacing on the yield and yield contributing characters of T. aman rice (var. BRRI dhan31) and found that panicle length increased with the increase of nitrogen rate up to 150 kg N ha⁻¹ and thereafter declined. The longest panicle (24.50

cm) was observed when 150 kg N ha⁻¹ was applied and the shortest (18.15 cm) from control. Nitrogen nutrient takes part in panicle formation as well as panicle elongation and for this reason, panicle length increased with the increase of N-fertilization up to 150 kg N ha⁻¹.

Salahuddin *et al.* (2009) reported that the highest number of grains panicle⁻¹ (109.79) was obtained at 150 kg N ha⁻¹, which was significantly different from other N levels. Nitrogen helped in proper filling of seeds which resulted higher produced plump seeds and thus the higher number of grains panicle⁻¹. The lowest number of grains panicle⁻¹ (99.41) was obtained from 0 kg N ha⁻¹.

Oikeh *et al.* (2008) conducted experiment on the effect of nitrogen on the upland NERICA rice cultivars in Nigeria which indicated no significant influence of nitrogen on grain size but it is contrast with the result of Fageria and Baligar (2001) who reported that the weight of 1000-grain increased significantly and quadratically with increasing nitrogen rates in Brazil. Other studies reported that the weight of 1000-grain decreased with increasing nitrogen rates (Mauad *et al.*, 2003).

Field experiments were conducted by Ravi *et al.* (2007) at Annamalai University Experimental Farm (Tamil Nadu, India) during Navarai and Kuruvai season to study the effect of foliar spray of phytohormones and nutrients on the yield and nutrient uptake of transplanted rice cv. ADT 36. The results revealed that foliar application of miraculan @1000 ppm recorded an added beneficial effect over other treatments.

Surekha *et al.* (2006) reported that the weight of 1000-grain was not affected significantly by crop management practices. Nitrogen application significantly increased 1000-grain weight (Singh *et al.*, 2006).

Singh *et al.* (2006) showed that the nitrogen application significantly increased plant height.

Alam *et al.* (2006) reported that straw yield increased with increasing N levels in rice.

Chu Van Hach and Nguyen Thi Hong Nam (2006) conducted a field experiment in Vietnam during the rainy and summer seasons of 2004 to study the effects of N fertilizer on the growth, yield components and economic efficiency of rice cultivars. During the rainy season, the main plots consisted of 5 rates of N fertilizer (urea) i.e. 0

(control), 30, 60, 90 and 120 kg ha⁻¹. In the summer season, the 5 rates of N fertilizer were control were 0, 40, 80, 120 and 160 kg N ha⁻¹. The results showed that the application of N fertilizer at 60 kg ha⁻¹ resulted in the greatest economic efficiency during the rainy season for all cultivars; further increase in the rate of N fertilizer beyond 90 kg N ha⁻¹ gave a negative economic efficiency value. During the dry season following the application of 80 kg N ha⁻¹ the economic efficiency value was highest for all cultivars. At higher nitrogen rates (120-160 kg N ha⁻¹), economic efficiency values were lowest.

Mazumder *et al.* (2005) reported that different levels of nitrogen influenced grain, straw and biological yields with the application of 100% recommended dose (RD) of N (99.82 kg N ha⁻¹) which was statistically followed by other treatments in descending order. The highest grain yield (4.86 t ha⁻¹) was obtained with 100% RD of N and the lowest (3.80 t ha⁻¹) from no application of nitrogen.

Chopra and Chopra (2004) showed that nitrogen had significant effects on yield attributes such as plant height, panicle plant⁻¹ and 1000-grain weight.

Singh *et al.* (2000) stated that each incremental dose of N gave significantly higher grain and straw yields of over pre-seeding dose, consequently the crop fertilized with 100 kg N ha⁻¹ gave maximum grain yield.

2.1.2 Phosphatic fertilizers

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

Islam *et al.* (2010) conducted a field experiment with five phosphorus rates (0, 5, 10, 20 and 30 kg P ha⁻¹) with four rice genotypes in Boro (BRRI dhan 36, BRRI dhan 45,

EH₁ and EH₂) and T. Aman (BRRI dhan 30, BRRI dhan 49, EH₁ and EH₂) season. Phosphorus rates did not influence grain yield irrespective of varieties in T. aman season while in Boro season P response was observed among the P rates. Application of P @ 10 kg ha⁻¹ significantly increased the grain yield. But when P was applied @ 20 and 30 kg P ha⁻¹, the grain yield difference was not significant. The optimum and economic rate of P for T. Aman was 20 kg P ha⁻¹ but in Boro rice the optimum and economic doses of P were 22 and 30 kg ha⁻¹, respectively. Hybrid entries (EH₁ and EH₂) used P more efficiently than inbred varieties. A negative P balance was observed up to 10 kg P ha⁻¹.

Dunn and Stevens (2008) conducted a field experiment to evaluate the effect of polymer coating of phosphate fertilizer on rice yield. Three rates of phosphate fertilizer, including polymer coated and non coated, were compared to an untreated check. Net return was calculated based on crop price and input costs. At the rate of 25 lb/acre P₂O₅ rate the polymer coated treatments produced greater yields than equivalent non coated treatments. At higher P₂O₅ rates both polymers coated and non coated treatments produced equivalent yields. The 25 lb P₂O₅ coated TSP treatment produced the greatest returns to producers.

Li *et al.* (2007) conducted an experiment to evaluate the contributions of rice root morphology and phosphorus uptake kinetics to P uptake by rice from iron phosphates. The Fe-P treatment significantly (P<0.05) decreased plant dry weight, P uptake per plant, and P concentration in plant dry matter of all cultivars in comparison with the control plants. In Fe-P treated plants, significant (P<0.05) genotype variation was shown in root morphology including root length, surface area, volume and number of lateral roots. The P uptake per plant from Fe-P by rice was significantly (P<0.05) correlated with root surface area and root volume as well as with the number of lateral roots suggesting that the ability of rice to absorb P from Fe-P was closely related to root morphology.

Das and Sinha (2006) conducted a field experiment on sandy loam soil during the kharif season of 2000 to study the effects of the integrated use of organic manures and various rates of N (urea) on the growth and yield of rice cv. IR 68. Among the different sources of organic amendments, farmyard manure (FYM; 10 t ha⁻¹) was superior, followed by the incorporation of wheat straw (5 t ha⁻¹) along with the

combined application of phosphates rock ($40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) and N. Grain and straw yields were highest when FYM was applied with 90 kg N ha^{-1} , although this treatment was comparable with combined application of wheat straw, phosphate rock and 90 kg N ha^{-1} .

Moula (2005) conducted an experiment on T. aman rice with different phosphorus rates. He found that when four treatments (P_0 , 60 kg ha^{-1} phosphate rock, 60 kg ha^{-1} TSP and 210 kg ha^{-1} phosphate rock) were applied, 210 kg phosphate rock (PR) showed better performance on yield contributing characters and nutrient content as well as nutrient uptake by rice over other treatments.

Nair and Rajasree (2004) conducted a field experiment to assess comparative efficiency of super phosphate and PR (34/74) at different levels in the yield characters and composition of rice. The treatments were 30 and $45 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ in the form of superphosphate and PR (34/74) with and without organic matter (6 t ha^{-1}), green manure (10 t ha^{-1}) and iron pyrites (10% by weight). The results showed that high grade phosphate rock (M, 34/74) with organic manure performed well and were followed by PR (34/74) with iron pyrites and green manure. Thus, PR (34/74) performed well with organic matter, FeS_2 and green manure in deciding growth and yield of rice. Higher contents of N, P, K, Ca and Mg of grain and straw were obtained at higher levels of $45 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ treatment.

2.1.3 Potassic fertilizers

Wang *et al.* (2011) carried out a field experiment to study the effects of N, P and K fertilizer application on grain yield, grain quality as well as nutrient uptake and utilization of rice to elucidate the interactive effects among N, P and K in a field experiment with four levels of nitrogen (N), phosphorus (P) and potassium (K) fertilizers. The results showed that the application of N, P and K fertilizer significantly increased grain yield, and the highest yield was found under the combined application of N, P and K fertilizer.

Wan *et al.* (2010) conducted an experiment to evaluate the effects of application of fertilizer, pig manure (PM), and rice straw (RS) on rice yield, uptake, and usage efficiency of potassium, soil K pools, and the non-exchangeable K release under the

double rice cropping system. The field treatments included control (no fertilizer applied), NP, NK, NPK, and NK + PM, NP + RS, NPK + RS. The application of K fertilizer (NPK) increased grain yield by 56.7 kg ha⁻¹ over that obtained with no K application (NP).

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

Muangstri *et al.* (2008) reported that the effect of rice straw and rice hull in combination with nitrogen, phosphorus and potassium fertilizer on yield of rice grown on Phimai soil series. The investigation carried out in pots. A completely randomized design with 3 replications was used. The treatments consisted of the control (without fertilizer) NPK fertilizer, rice straw at the rate of 0.75, 1.5 and 3.0 g kg⁻¹ soil in combination with NPK fertilizer, and rice hull at the rate of 0.75, 1.5, 3.0 and 4.5 g kg⁻¹ soil in combination with NPK fertilizer. The results showed that the growth, yield and nutrient uptake of rice plant grown on Phimai soil series without fertilizer were the lowest. Application of rice hull in combination with NPK fertilizer increased nutrient absorption and rice yield better than with NPK alone, especially at the rate of 1.5 g kg⁻¹ soil. Yield of rice plant grown on the soil amended with rice straw in combination with NPK fertilizer tended to be higher than that of rice plant grown on the soil amended with only NPK fertilizer.

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

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

Hu H *et al.* (2004) conducted a field experiment in Zhejiang, China, to investigate the K uptake, distribution and use efficiency of hybrid and conventional rice under different low-K stress conditions. The grain yield and total K uptake by rice increased, while the K use efficiency of rice decreased significantly. The interaction effect between cropping history and K application was also significant. The phase from panicle initiation to flowering was critical for K uptake by rice and more than half of the total plant K was accumulated during this phase.

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

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

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

Cong *et al.* (2001) found that K application improved yield of rice grown on an alluvial soil. Overall quality of crops was improved with K application though there was no generally accepted indicator according to which fertilizer effects on quality can be measured.

Singh *et al.* (2000) evaluated the effect of levels of K application on rice at different places. Results indicated that K application significant enhanced the growth and yield of rice over no application. The highest grain and straw yields of rice was obtained at 90 kg K₂O ha⁻¹ all the cropping seasons.

2.1.4 Sulphur fertilizers

Ji-ming *et al.* (2011) conducted a field experiment to study the effects of manure application on rice yield and soil nutrients in paddy soil. The results show that the long-term applications of green manure combined with chemical fertilizers (N, P, K, and S) are in favor of stable and high yields of rice.

Patel *et al.* (2010) conducted a field experiment to study the performance of rice and a subsequent wheat crop along with changes in properties of a sodic soil treated with gypsum, press mud and pyrite under draining and nondraining conditions in a greenhouse experiment. The highest rice yield was obtained with press mud applied at a rate of 50 and 75% gypsum requirement.

Manivannan *et al.* (2008) conducted a field experiment in sulfur deficient soils to study the response of rice genotypes to sulfur fertilization. The treatments consisted of three levels of sulphur (0, 20 and 40 kg ha⁻¹) applied through gypsum and 10 rice genotypes (ADT 36, ADT 37, ADT 42, ADT 43, ADT 38, ADT 39, CO 43, CO 45, CO 47 and ASD 19). The results revealed that rice genotypes differed significantly among themselves to growth and yield on S addition. Rice genotypes CO 43 (5,090 kg ha⁻¹) and CO 47 (5,243 kg ha⁻¹) recorded the highest grain yield.

Bhuvaneshwari *et al.* (2007) conducted a field experiment in Tamil Nadu, India during the 2001 kharif season to study the effect of sulphur at varying rates i.e. 0, 20, 40 and 60 kg ha⁻¹ with different organic fertilizers i.e. green manure, farmyard manure, sulfitation press mud and lignite fly ash each applied at 12.5 t ha⁻¹ on yield, S use efficiency and S optimization of rice cv. ADT 43. The results revealed that rice responded significantly to the application of S and organic compared to the control. The highest grain (5,065 kg ha⁻¹) and straw yield (7,525 kg ha⁻¹) was obtained with 40 kg S ha⁻¹ application. Green manure addition caused 8.9% increase in grain yield and 10.6% increase in straw yield, closely followed by sulfitation press mud. Sulphur use efficiency was highest at 20 kg ha⁻¹ and higher in the presence of organic fertilizers.

Bhuvaneshwari and Chandrasekharan (2006) conducted a field experiment in Annamalainagar, Tamil Nadu, India during the kharif season of 2001 to study the effects of organic manures and sulphur on yield and nutrient uptake by rice (cv. ADT-43). The treatments consisted of 4 levels of S (0, 20, 40 and 60 kg ha⁻¹) applied

through gypsum and various organic fertilizers (green manure, farmyard manure, sulfitation press mud and lignite flyash) applied at 12.5 t ha⁻¹ each. The sulphur and organic fertilizers significantly enhanced yield and nutrient uptake. The highest grain (5,065 kg ha⁻¹) and straw (7,524 kg ha⁻¹) yields, and uptake of N, P, K and S were obtained with the application of 40 kg S ha⁻¹. Sulphur use efficiency was greatest at 20 kg S ha⁻¹. Among the organic fertilizers green manure, closely followed by sulfitation press mud, registered the highest rice yield, sulphur use efficiency, and uptake of N, P, K and S.

Singh *et al.* (2005) conducted a field experiment during the kharif season on an Inceptisol in Varanasi, Uttar Pradesh, India to study the effect of S and Mn fertilizer application on the content and quality of bran oil of different rice cultivars viz. Pant-12 (short duration), Swarna (long duration) and Malviya-36 (medium duration). The treatments comprised S and Mn applied at 0, 25, 50 and 0, 10, 20 kg ha⁻¹ through gypsum and MnCl₂, respectively and their combinations. A uniform application of recommended doses of N, P and K was given in all the experimental plots. Application of both S and Mn significantly enhanced the bran content and yield of rice over the control. The highest dose of Mn and S on an average caused an increase of 15.2 and 45.0% in bran oil yield over the control, respectively. Increasing levels of S brought about noticeable increment in the percentage of unsaturated fatty acids, including PUFA indicating improvement in the quality of bran oil.

Azmi *et al.* (2004) studies on long-term influence of four fertility levels and management practices under rice-wheat-sorghum and rice-mustard-mungbean rotations on soil fertility build-up and the yield of crops are being carried out in a Calciorthent of Pusa, Bihar, India. Increasing fertility levels significantly increased the crop yield and S uptake under both rotations. Depth-wise distribution of available S was also studied from the same experiment and the results revealed that high fertility level increased the available S at all the soil depths investigated. However, at medium and high fertility, available S was almost equal beyond 30-45 cm depth under rice-wheat-sorghum rotation. Higher fertility reduced leaching losses to some extent. Accumulation of available S under rice-wheat-sorghum rotation was higher at all the depths as compared to rice-mustard-mungbean rotation due to higher amount of S added under the former rotation. However, S movement down the depth was more in case of rice-wheat-sorghum rotation. Rice-mustard-mungbean rotation removed more

S from surface soil but at the same time it restricted the downward movement up to only 45 cm.

Chandel *et al.* (2003) conducted a study to see the effect of sulphur nutrient on growth and sulphur content in rice and mustard grown in sequence. The experiment was laid out in split plot design with four sulphur levels (0, 15, 30 and 45 kg S ha⁻¹) applied to rice as main plot treatments during rainy season and each plot further divided into three subplots (0, 20 and 40 kg S ha⁻¹) applied to mustard during winter season. They found that increasing sulphur levels in rice significantly improved leaf area index, tiller number, dry matter production, harvest index and sulphur content in rice up to 45 kg S ha⁻¹.

Singh and Singh (2002) carried out a field experiment to see the effect of different S levels (0, 20 and 40 kg ha⁻¹) on rice cv. Swarna and PR 108 in Varanasi, Uttar Pradesh, India. They reported that plant height, tillers m⁻², dry matter production, panicle length and grains panicle⁻¹ was significantly increased with increasing levels of S up to 40 kg ha⁻¹.

Sarfraz *et al.* (2002) conducted a field experiment to determine the effect of different S fertilizers at 20 kg ha⁻¹ on crop yield and composition of rice cv. Shaheen Basmati in Pakistan. They found that the number of tillers m⁻², 1000-grain weight, grain and straw yields were significantly increased with the application of NPK and S fertilizers compared to the control. They also found that NPK concentrations and their uptake in grain and straw significantly increased with the application of NPK + S fertilizers compared to the control. They also found that NPK concentrations and their uptake in grain and straw significantly increased with the application of NPK + S fertilizers compared to the control.

Peng *et al.* (2002) conducted a field experiment where one hundred and sixteen soil samples were collected from cultivated soils in Southeast Fujian, China. Field experiments showed that there was a different yield increasing efficiency with application S at the doses of 20-60 kg ha⁻¹ to rice plant. The increasing rate of rice yield was 2.9-15.5% over control. A residual effect was also observed.

Yang *et al.* (2001) studied the effects of sulphur fertilizer and nitrogen sulphur fertilizers with rice cv. Weiyou 63 in Fujian, China and found that in S fertilizer

treated plots (6.9 mg available S kg⁻¹ soil) fertilized with 20 and 40 kg N ha⁻¹. Plants had a greater number of panicles and higher fertility than control plants without S fertilizer treatment. On the other hand in NS treated plots (receiving N rates of 0, 150 and 210 kg ha⁻¹, and S rates of 0, 30 and 60 kg ha⁻¹) the highest yield 8850 kg ha⁻¹ was obtained with 150 kg N ha⁻¹ + 60 kg S ha⁻¹. However, they further stated that the optimum ratio for NS fertilizer was 4:1.

Yang *et al.* (2001) studied the effects of sulphur fertilizer and nitrogen-sulphur fertilizers with rice cv. Weiyou 63 in Fujian, China and found that S treated pots (6.9 mg available S kg⁻¹ soil) fertilized with 20 and 40 kg N ha⁻¹ had a greater number of panicles and higher fertility than control plants. On the other hand, in NS treated plots (received N rate of 0, 150 and 210 kg ha⁻¹ and S rate of 0, 30 and 60 kg ha⁻¹) the highest yield (6,850 kg ha⁻¹) was obtained with 150 kg N ha⁻¹ + 60 kg S ha⁻¹.

Raju and Reddy (2001) conducted field investigations at Agricultural Research Station, Maruteru, Andhra Pradesh, India to study the response of both hybrid and conventional rice to sulphur (at 20 kg ha⁻¹) and zinc (at 10 kg ha⁻¹) applications. Significant improvement in grain yield was observed due to sulphur application.

Vaiyapuri and Chandrasekharan (2001) conducted an experiment on integrated use of green manure (3.5 t ha⁻¹) with graded levels of sulphur (0, 20 and 40 kg ha⁻¹) applied through three different sources in rice cv. ADT 37. They reported that the highest rice yield (5.3 t ha⁻¹) was obtained when green manure was applied along with pyrite at 20 kg S ha⁻¹ which was comparable with pyrite applied at 40 kg ha⁻¹ in the absence of green manure.

Mandal *et al.* (2000) carried out a greenhouse experiment to evaluate the effect of N and S fertilizers on nutrient content of rice grains (cv. BR 3) at various growth stages (tillering, flowering and harvesting). Nitrogen was applied as urea and S as gypsum @ 0, 5, 10 and 20 kg S ha⁻¹. The combined application of these two elements increased the straw S content only at tillering stage. The uptake of nutrient by the straw and grain increased significantly, which was reflected in the straw and grain yields.

2.2 Effects of organic manure on the growth and yield of rice

Morteza *et al.* (2011) conducted an experiment in order to study the effect of organic fertilizer on growth and yield components in rice. The chicken manure, cow dung and paddy rice were mixed together in 1: 1: 0.5 ratios from organic fertilizer. The treatments of organic fertilizer were given in 5 levels (0.5, 1.0, 1.5, 2.0 and 2.5 t ha⁻¹). An increase in the grain yield at the above mentioned treatments may be due to the increase of 1000-seed weight, panicle number, number of fertile tiller, flag leaf length, number of spikelet, panicle length and decrease number of hollow spikelet per panicle.

Solaiman *et al.* (2011) conducted a field experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University Research Farm, Gazipur during boro season to evaluate and examine the effect of urea- nitrogen, cowdung, poultry manure and urban wastes on growth and yield of boro rice, cv. BRRI Dhan 29. The yield was significantly increased where urea, cowdung, poultry manure and urban wastes are applied together.

Naing *et al.* (2010) conducted a field experiment to investigate the effect of organic (cowdung) and inorganic fertilizers on growth and yield of five upland black glutinous rice varieties and soil property. Soil samples before fertilizer application and after harvesting were analyzed to determine chemical and [physical properties](#). Leaf Area Index (LAI) and shoot [dry matter](#) were recorded at 40 days after planting, panicle initiation and flowering stages. Number of tillers and panicles per hill and grains per panicle, thousand grain weight, number of filled and unfilled grains and [grain yield](#) were recorded at harvest time. The results indicated that using the combination of FYM, cowdung and inorganic fertilizers increased shoot [dry matter](#), leaf area index (LAI), tiller and panicle number per hill, grain number per panicle and [grain yield](#) and soil P and K content.

Yadav *et al.* (2010) conducted a field experiment to find the efficacy of substituting fertilizer N at different proportions (25%, 50% and 75% of total N) with organic N sources i.e., farm yard manure (FYM), green leaf manure (GLM), poultry manure and BGA on nutrient uptake (NPK) and yield of rice variety Sarju 52. In general the maximum uptake of the nutrients and grain yield were obtained with the application

of 25% N through green manure + 75% through inorganic urea. GLM is more efficient than other organic sources at all the proportions of N.

Debiprasad *et al.* (2010) conducted a field experiment to investigate the effect of enriched pressmud compost on soil chemical properties like pH, EC, nutrient content. Application of 120 kg N ha⁻¹ through chemical fertilizer and combination of press mud and cowdung increased effective tillers m⁻² number of effective tillers m⁻², filled grains per panicle, 1000-grain weight.

Uddin *et al.* (2009) conducted a field experiment to study the effects of S, Zn and B supplied from chemical fertilizers and poultry manure on yield and nutrient uptake by rice (cv. BRRI Dhan-30). The different nutrients significantly increased plant height, effective tillers hill⁻¹, filled grains panicle⁻¹, 1000-grain weight, grain and straw yields of rice. The highest grain yield of 4,850 kg ha⁻¹ was obtained when S, Zn and B were applied combination with poultry manure.

Gedam *et al.* (2008) carried out a field experiment to study the residual effect of organic manures on growth, yield attributes and yield of rice in groundnut-rice cropping system. It was observed that residual effect of organic manures significantly affected the grain yield of succeeding rice. Application of poultry manure at the rate of 5 t ha⁻¹ to groundnut increased the grain yield of rice significantly over the remaining treatments. The grain yield of rice ranged from 30.54 q ha⁻¹ in control plot to 46.52 q ha⁻¹ due to residue of poultry manure applied to groundnut. Similarly, the direct effect of fertilizer applied to rice was significant in increasing the yield of rice.

Kumar *et al.* (2008) conducted a field experiment on rice-wheat system revealed that the values of all yield attributes were improve significantly due to integrated use of press mud along with recommended doses of fertilizer (RDF). Rice received 10 t press mud ha⁻¹ along with RDF produced significantly higher grain yield.

Vennila (2007) conducted a field experiment in rabi season to develop integrated N management practice for wet seeded rice (cv. ADT 38) + daincha dual cropping systems. They reported that 75% recommended dose of N fertilizer + 25% N as poultry manure increased growth, yield attributes and yield and nutrient uptake of rice higher soil available organic carbon, nitrogen and phosphorus.

Kalaivanan and Oma (2007) conducted a field experiment to investigate the effect of enriched pressmud compost on soil chemical properties like pH, EC, major nutrient availability and yields of rice with five levels of pressmud compost viz. 0, 1.25, 2.50, 3.75 and 5.0 t ha⁻¹ in three varieties viz. ADT 36, ADT 43 and a hybrid ADTRH 1 during the kharif season. The results of the field experiment revealed that the hybrid ADTRH 1 manifested higher grain and straw yield, whereas the variety ADT 43 and ADT 36 registered lower grain and straw yields, respectively. Application of 1.25 t ha⁻¹ of enriched pressmud compost showed its potentiality by providing more available nutrients to promote higher grain yield and it was comparable with 2.50 t ha⁻¹ of enriched pressmud compost.

Singh *et al.* (2006) conducted an experiment during kharif 2004, on an Inceptisol in Varanasi, Uttar Pradesh, India to evaluate the effects of chemical fertilizer (urea), cowdung and biofertilizer (*Azospirillum*) on the yield of rice and physicochemical properties of the soil. Application of chemical fertilizer, cowdung and *Azospirillum*, individually or in combinations, significantly increased the yield attributes (plant height, number of tillers, panicle length, grain yield and straw yield) over the control. The treatment comprising 80 kg N ha⁻¹ + *Azospirillum* + 2.5 t cowdung ha⁻¹ was superior over all other treatments in terms of rice yield.

Kumar and Singh (2006) 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 attribute of rice (*Oryza sativa* cv Pusa Basmati). The manure treatments comprised organic manures farmyard manure (FYM), poultry manure (PM) and FYM + PM. Fertilizer treatment included N at 0, 40, 80 and 120 kg ha⁻¹. The maximum mean grain yield (45.4 q ha⁻¹) was recorded FYM + PM with N, P and Zn treatment. Over the years, incorporation of FYM, PM and FYM + PM and zinc application along with N in both the years of study significantly increased grain yield of rice over 40 kg N ha⁻¹ and in pooled analysis.

Reddy *et al.* (2006) carried out a field experiment for two years (2001 and 2002) on the farmers field in Koler district (eastern dry zone, Karnataka, India) to study the effect of different organic manures on growth and yield of paddy under tank

irrigation. Application of poultry manure (9 t ha^{-1}) to paddy produced grain yields at recommended dose of fertilizers + 10 t ha^{-1} FYM but both were higher (67 and 69%) respectively than FYM. Poultry manure produced better growth components viz. plant height, number of tillers hill^{-1} , and total dry matter plant^{-1} and yield components like number of panicle hill^{-1} and panicle length.

Mashkar and Jhora (2005) conducted a field experiment at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, during August to December 1995 to study the transplanted aman rice. Four varieties, namely, BR10, BR11, BR22 and BR23 and five fertilizer application treatments namely, F_1 = inorganic fertilizers (IF), F_2 = IF + cowdung 5 t ha^{-1} , F_3 = IF + cowdung 10 t ha^{-1} , F_4 = recommended doses N application + cowdung 5 t ha^{-1} , and F_5 = IF with recommended doses N application + cowdung 10 t ha^{-1} . Cowdung up to 10 t ha^{-1} in addition to recommended inorganic N fertilizer application improved grain and straw yields and qualities of transplant rice over inorganic fertilizers alone.

Ogbodo (2005) conducted a study to compare the response of rice to organic and inorganic manures at Abakaliki, Southeastern Nigeria between 2002 and 2003 cropping seasons (April-November). However organic manure application doses of over 20 t ha^{-1} reduced plant growth and grain yield.

Yaduvanshi and Sharma (2005) conducted a field experiment during 2001–02 and 2002–03 at Bhaini Majra experimental farm of Central Soil Salinity Research Institute, Karnal (Haryana) to evaluate the effect of management of wheat residue with *Sesbania* green manuring and sulphitation pressmud (SPM) on soil properties and yield of rice and wheat crops irrigated with sodic water. The results suggest that incorporation of wheat residue 50 days before rice transplanting with green manuring or with sulphitation pressmud along with the recommended dose of fertilizer is necessary to improve and sustain the productivity of rice-wheat system in areas having sodic water.

Mahavishnan *et al.* (2004) conducted a field study on sandy clay loam soil of Hyderabad Andhra Pradesh, India during the kharif season of 2000 to investigate the effect of nutrient management through organic and inorganic sources on the yield of rice cv. BPT 5204. The treatments included: control, fertilizer rate 75% of the recommended rate of fertilizers (RDF= N: P: K at $120:60:40 \text{ kg ha}^{-1}$), 100% RDF,

125% RDF, 125% RDF + farmyard manure at 10 t ha⁻¹. Rice yield and yield components were higher with the application of 125% RDF + PM compared to the other treatments.

Usman *et al.* (2003) conducted a field experiment to study the effects of organic amendment (FYM, poultry manure) on the performance of rice cv. Basmati-2000 was investigation in Faisalabad, Pakistan. Poultry manure showed the maximum leaf area index (46.46%). The treatment also produced the highest number of grains panicle⁻¹, 1000-grain weight and straw yield.

Channabasavanna and Biradar (2003) observed that grain yield increased with each increment of poultry manure application and maximum in 3 t poultry manure ha⁻¹ which was 26 and 19% higher than that of the control during 1998 and 1999 respectively and the increase was significant up to 2 t poultry manure ha⁻¹.

More (2003) reported from a 3 year study that the treatment of 25 t FYM ha⁻¹ plus 20 t pressmud ha⁻¹ was found to be the best in increasing yield of rice.

Vanaja and Raju (2002) conducted a field experiment for one year during 1996-97, in sandy loam soil having pH of 8.4 at Student's Farm College of Agriculture, Hyderabad. Organic manures (Cowdung, poultry manure) and biofertilizers (BGA, *Azospirillum*) alone and in combination with inorganic fertilizer nitrogen were studied on rice crop. The relationship between total dry matter production at maturity and total uptake of nutrients (N, P and K) was highly significant.

Chettri *et al.* (2002) conducted a field experiment in a sandy clay loam soil of neutral reaction having 0.067, 17, 19.3 and 17.2 kg ha⁻¹ available N, P, K and S, respectively in Nadia, West Bengal, India during 1994-95 and 1995-96. The highest number of effective tillers hill⁻¹, grains panicle⁻¹, percentage of filled grains, 1000-grain weight, grain yield (44.05 q ha⁻¹) of rice were obtained with the application of 60 kg N, 30 kg P₂O₅ and 30 kg K₂O ha⁻¹ with 10 t cowdung ha⁻¹.

Azad and Leharia (2002) conducted a field experiment during Kharif of 1995 and 1996 in Jammu, India to investigate the effect to NPK application with and without poultry manure (PM at 10 t ha⁻¹) and Zn (as ZnSO₄ at 20 kg ha⁻¹) on growth and yield of rice cv. PC-19. Results indicated that application of poultry manure in combinations with different NPK levels exhibited a significant increase in effective

tillers m^{-2} area in row, grain and straw yields over NPK, a significant increase in growth and straw yield ($1,318 \text{ kg ha}^{-1}$) yields were recorded from T_7 and the lowest from T_4 .

Saitoh *et al.* (2001) conducted an experiment to evaluate the effect of organic fertilizers (cowdung and chicken 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 decrease in the number of panicle.

Singh and Prasad (2001) reported that the application of FYM @ 10 t ha^{-1} produced 4.64 % higher grain yield than the control.

Channabasavanna and Biradar (2001) conducted an experiment with four sources of organic manure (FYM 7 t ha^{-1} , rice husk 5 t ha^{-1} , poultry manure 2 t ha^{-1} and press mud 2 t ha^{-1}), one control and 3 levels of zinc (0, 25 and $50 \text{ kg ZnSO}_4 \text{ ha}^{-1}$). Application of poultry manure with $25 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ recorded significantly higher yields over rest of the treatments. The residual effect was more prominent when rice husk was applied. They also cited that organic manure increased panicle hill^{-1} and seeds panicle^{-1} .

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

Ram *et al.* (2000) reported that the use of 30 or 60 kg N ha^{-1} from organic sources in a total application of 120 kg N ha^{-1} increased grain and straw yields, N uptake and recovery, grain nutritive value, decreased soil pH and increased soil fertility and economic returns.

2.3 Combined effects of manures and fertilizers on the growth and yield of rice and soil properties

Chaudhary *et al.* (2011) conducted a field experiment at Pusa, Bihar to study the effect of inorganic fertilizer in combination with organic sources viz. vermicompost, poultry manure, FYM and green manuring under four dates of transplanting on rice. Maximum grain yield (4.12 t ha^{-1}) was with 75% recommended dose of nitrogen (RDN) + 25% N from dhaincha (*Sesbania aculata L.*) and it was 14.8 and 26.1% higher over 100 and 75% RDN, respectively. The result shows that there was significant reduction in yield attributes, yields and nutrient uptake due to delayed transplanting.

Chun-yan *et al.* (2011) carried out an experiment to study the effect of fertilization on yield and nutrients absorption in japonica rice variety Zhejing 22. The results showed that rational combination of chemical fertilizers and manure showed better effect on rice yield, and the efficiency of fertilizers and absorption of nutrients increased.

Balakrishnan *et al.* (2010) conducted a experiments at Port Blair, to evaluate prickly sesban (*Sesbania cannabina*) intercropping in wet-seeded rice under island ecosystem. The result was revealed that though chemical fertilizer + dhaincha or prickly sesban gave higher grain yield and also increased the soil organic matter content.

Singh *et al.* (2010) conducted a experiment to study the effect of N, P and K fertilizers with or without FYM, lime, sulphur and boron on yield, nutrient uptake and fertility status of soil available N, P, K and S. The highest grain yield of rice and pea was recorded in the treatment receiving 50% of recommended dose NPK fertilizers along with application of $5 \text{ t FYM} + 250 \text{ kg lime} + 20 \text{ kg S} + 1 \text{ kg B ha}^{-1}$. Application of lime @ 250 kg ha^{-1} in furrows along with 5 t FYM ha^{-1} and 50% RDF significantly improved the pH of soil after harvest of pea crops.

Kabir *et al.* (2009) conducted a experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh in transplanted *Aman* season 2008 to find out the effect of urea super granules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield attributes of transplant *Aman* rice varieties. Two transplant *Aman* rice varieties viz. BRR1 dhan 41 and BRR1 dhan 46 and ten levels of

integrated nutrient management encompassing USG, PU and PM were tested following randomized complete block design with three replications. It was observed that combined use of chemical fertilizer and manure gave the higher yield of rice and improvement of soil fertility P, K and S content.

Ju-mei (2008) conducted a field experiment to investigate the effects of chemical and organic fertilizers on rice yield, soil organic matter and soil nutrients. The combined use of chemical and organic fertilizers was an optimum way for high yield and improvement of soil fertility. Combined use of chemical fertilizer and manure were showed the higher yield of rice and improvement of soil fertility.

Naik and Yakadri (2007) conducted a field experiment in Hyderabad Andhra Pradesh, India during 2001 wet season to determine the effect of integrated nutrient management on the yield of rice hybrid DRRH-1. The treatments comprised: in the main plots no organic manure (control), green manuring (*Sesbania rostrata*), 10 t farmyard manure ha⁻¹, 2 t gemini compost/ha, 2 t vermicompost ha⁻¹, and 2 t rice husk ash ha⁻¹, in the subplots 50, 100 and 150 kg N ha⁻¹. In green manuring and 150 kg N ha⁻¹ fertilizer gave the highest dry matter at harvest, effective tillers m⁻², filled grains panicle⁻¹, grain yield, straw yield, organic C content and cost-benefit ratio. Rice treated with in situ green manuring + 150 kg N ha⁻¹ fertilizer produced the highest grain yield.

Sreelatha *et al.* (2006) conducted a field experiment during 1997/98, in Srikakulam, Andhra Pradesh, India, to evaluate the effects of different integrated nutrient management (INM) components on the yield and nutrient uptake in mesta (*Hibiscus cannabinus*) - rice cropping system. Recommended fertilizer dose of 75 kg N ha⁻¹ with 5 t cowdung ha⁻¹, recorded the highest Mesta fiber yield of 25.32 q ha⁻¹ as well as the highest rice grain and total (grain + straw) yields of 28.82 and 64.06 q ha⁻¹ respectively. The result also showed that N, P and K content in soil were increased due to application of fertilizer and cowdung.

Singh *et al.* (2005) conducted multi-locational experiments at eight farmers field covering five villages (Pairaguri, Puturu, Gidhibill, Kuliya and Deoli) of east Singhbhum, Jharkhand, India in kharif seasons of 2001 and 2002 to study the effect of integrated nutrient management (INM) practices on transplanted rice yield and nutrient uptake and soil fertility status. Results showed that the grain and straw yields

of transplanted rice were significantly influenced by INM practices. NPK (80:60:30 kg ha⁻¹) + 5 t FYM ha⁻¹ + cowpea as green manure recorded the highest grain yield. The total N, P and K uptake by rice was higher with INM practices over the farmers practice. Available N, P and K content in farmer's field was improved under INM practices compared to its initial soil fertility.

Patra *et al.* (2004) conducted a field experiment in kharif 1999 to determine the influence of top dressing *Sesbania sesban* green manure with urea on the nitrogen (N) content of the soil (Typic Ustochrept) and yield of hybrid rice. Results showed that the application of *S. sesban* green manure consistently maintained a lower floodwater pH than the treatment with urea alone. A lower pH of the floodwater has an important implication in flooded rice soils particularly to lowering NH₃ and thereby reducing NH₃ losses. Results indicated that the top dressing of *S. sesban* along with urea has the potential to enhance the yield and N use efficiency of flooded hybrid rice.

Mahavishnan *et al.* (2004) conducted a field study on the effect of nutrient management through organic and inorganic sources on the yield of rice cv. BPT 5204. Rice yield and yield components were higher with the application of 125% recommended dose of fertilizers RDF + poultry manure (PM) compared to the other treatments.

Vipin-Kumar (2003) carried an experiment in Nigeria to determine the effect of goat manure on upland rice. The applications of 10 t ha⁻¹ and 20 t ha⁻¹ of goat manure produced 1.49 t ha⁻¹ and 1.58 ton ha⁻¹ grain yields, respectively in the second year. These yields were as good as those obtained with application of chemical fertilizer only or the application of 10 t ha⁻¹ of goat manure + top-dressing with 30 kg N ha⁻¹. The application of 30 t ha⁻¹ goat manure produced the highest grain yield increase but resulted in more weed and stem borer infestation in those plots.

Abro and Abbasi (2002) conducted a field experiment in randomized complete block design with six replication on rice variety DR-82 at Agriculture Research Institute, Dokri. The result indicated that highest grain yield 5,525 kg ha⁻¹ was obtained when green manuring applied with chemical fertilizer at the rate of 90-60 kg ha⁻¹.

Rajni Rani *et al.* (2001) conducted a pot experiment in a glasshouse of Varanasi, Uttar Pradesh, India during kharif season to assess the response of rice to different

combinations of vermicompost, poultry manure and nitrogen fertilizers. Results showed that all integrated treatments significantly increased plant height, number of effective panicles pot^{-1} and dry weight panicle $^{-1}$ over the treatment having full N dose through urea.

Rahman (2001) reported that in rice-rice cropping pattern, the highest grain yield of boro rice was recorded in the soil test basis (STB) NPKSZn fertilizers treatment while in T. aman rice the 75 % or 100 % of NPKSZn (STB) fertilizers plus cowdung gave the highest or a comparable yield.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, under the Agro Ecological Zone-28 of Madhupur Tract, during the *Late T-Aman* season of 2012. For better understanding the site, it is shown in the Map of AEZ of Bangladesh (Fig.1).

This chapter presents a brief description of the soil, crop, experimental design, treatments, cultural operations, collection of soil and plant samples and analytic methods followed in the experiment. This chapter has been divided into a number of sub-heads describe as below:

3.1 Experimental details of site

3.1.1 Soil

The experiment was carried out in a typical rice growing soil of the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka, during *Late T-Aman* season of 2012. The farm belongs to the General soil type, "Deep Red Brown Terrace Soil" under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of initial soil are presented in Tables 1 and 2.

3.1.2 Crop

NERICA 10 a short duration rice variety first introduced in Bangladesh in 2009 from Africa was used as a test crop. It is not only a drought tolerant but also drought avoidance variety and fast recovery with rains after drought.

3.1.3 Land preparation

The experimental field was first opened on 10 August 2012 with the help of a power tiller, later the land was saturated with irrigation water and puddled by three successive ploughing and cross-ploughing. Each ploughing was followed by laddering to have a good puddled

field. All kinds of weeds and residues of previous crop were removed from the field. The experimental plots were laid out as per treatment and design.

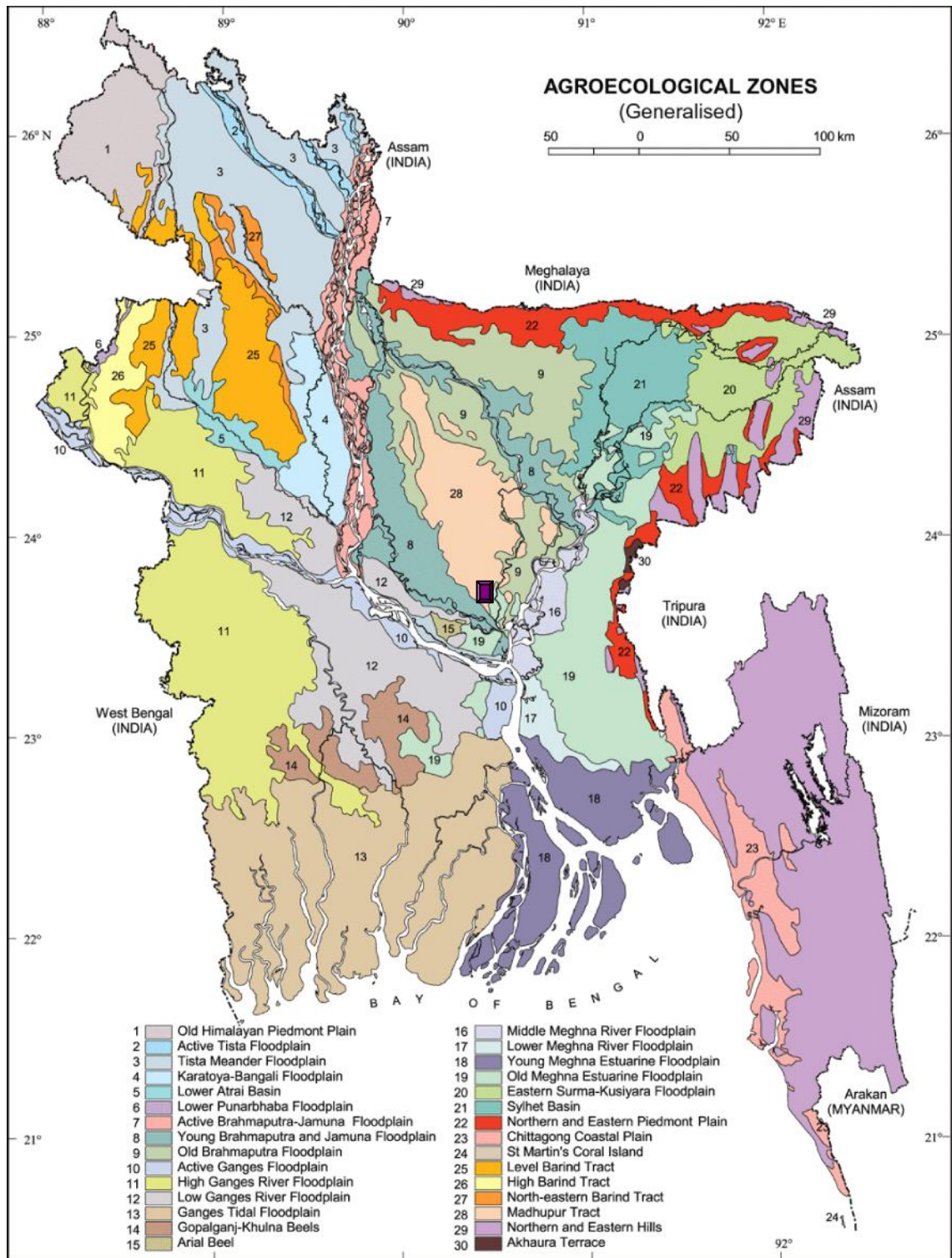


Figure 1. Map showing the experimental site under study

Table 1. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ	Madhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Table 2. Physical and chemical properties of the initial soil sample

Characteristics	Value
Particle size analysis	
% Sand	28.2
% Silt	41.2
% Clay	30.6

Textural class	Silty-clay
pH	5.6
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.52
Organic carbon (%)	0.47
Organic matter (%)	0.81
Total N (%)	0.05
Available P (ppm)	18.1
Exchangeable K (meq/100g soil)	0.10
Available S (ppm)	22

3.1.4 Experimental design

Design: Randomized Complete Block (RCB).

Treatment: 11

Replication: 3

Total number of plots: 33

Plot size: 4 m × 3 m

Block to block distance: 1 m

Plot to plot distance: 50 cm

3.1.5 Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with two factors and three replications. Each block was sub-divided into eleven unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of

plots was 33 (11×3). The unit plot size was 4 m × 3 m. Block to block distance was 1 m and plot to plot distance was 50 cm. The layout of the experiment has been shown in Fig. 2.

3.1.6 Seed sowing

A standard procedure was followed to sow the seeds of NERICA 10 rice in field. For this purpose, 5 to 7 seeds were sown per stand and later thinned to 4 seedlings at 17 days old. Stand to stand distance was 12 cm.

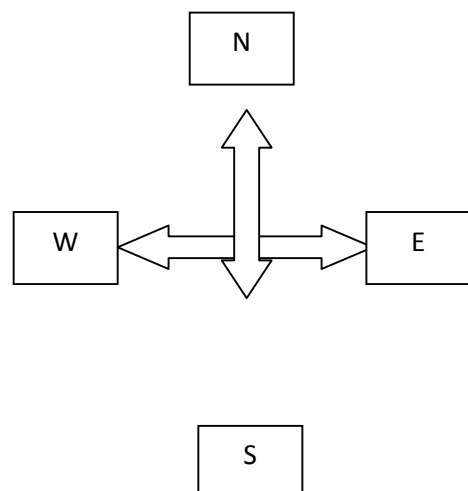
3.1.7 Collection and preparation of initial soil sample

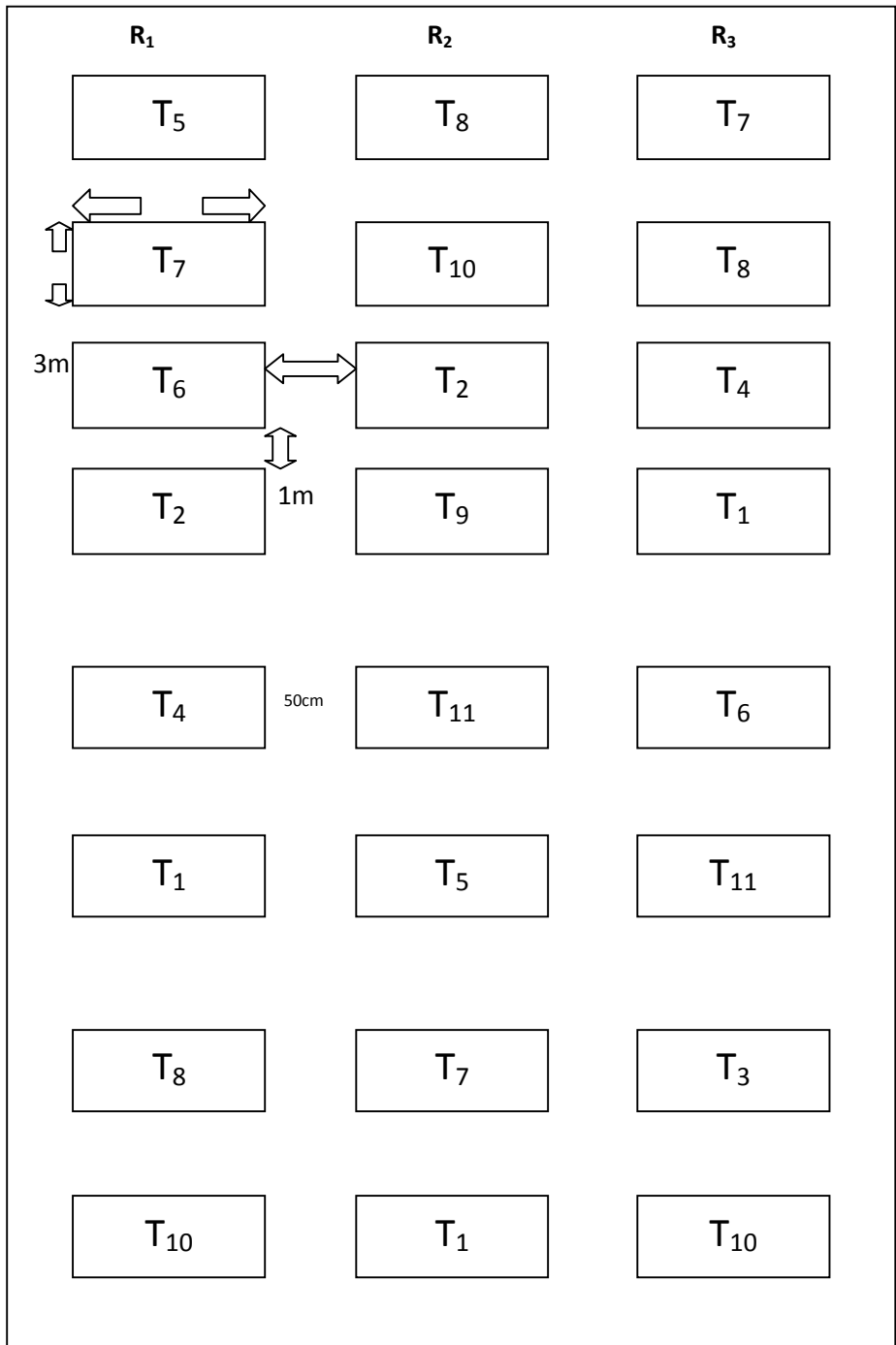
The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

Plot size: 4 m x 3 m

Plot to plot distance: 50 c m

Block to block distance: 1 m





T_{11}

T_6

T_{52}

T_3

T_4

T_9

T_9

T_3

T_5

Figure 2. Layout of the experimental field

3.1.8 Treatments

There were 11 treatment combinations. The treatment combinations were as follows:

T₁: No chemical fertilizer, no organic manure (Control)

T₂: 100% recommended N (120 kg nitrogen ha⁻¹) + recommended P,K,S,Zn

T₃: 100 kg N from urea + 20 kg N substituted by vermicompost + recommended P,K,S,Zn

T₄: 100 kg N from urea + 20 kg N substituted by cowdung + recommended P,K,S,Zn

T₅: 80 kg N from urea + 40 kg N substituted by vermicompost + recommended P,K,S,Zn

T₆: 80 kg N from urea + 40 kg N substituted by cowdung + recommended P,K,S,Zn

T₇: 60 kg N from urea + 60 kg N substituted by vermicompost + recommended P,K,S,Zn

T₈: 60 kg N from urea + 60 kg N substituted by cowdung + recommended P,K,S,Zn

T₉: 40 kg N from urea + 80 kg N substituted by vermicompost + recommended P,K,S,Zn

T₁₀: 40 kg N from urea + 80 kg N substituted by cowdung + recommended P,K,S,Zn

T₁₁: 100% N substituted by equal portion of vermicompost and cowdung + recommended P,K,S,Zn

Table 3. Nitrogen percentage in different elements in the experiment

Source	Nitrogen percentage
Urea	46%
Cowdung	0.5%
Vermicompost	2%

3.1.9 Application of fertilizers

The amounts of nitrogen, phosphorus, potassium and sulfur fertilizers required per plot were calculated from fertilizers rate per hectare. A blanket dose of 16 kg P, 60 kg K and 10 kg S hectare⁻¹ was applied to all plots in the forms of triple super phosphate (TSP), muriate of potash (MoP) and gypsum, respectively during final land preparation. Nitrogen was also applied as per treatment in the form of urea in three equal splits. The first split was applied after 15 days of sowing, the second split was applied after 35 days of sowing i.e. at active vegetative stage and the third split was applied after 60 days of sowing i.e. at panicle initiation stage.

3.1.10 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop. Top dressing of urea was done as per schedule and the normal cultural practices including weeding and insecticides spray were done as and when necessary. There were some incidence of insect attack specially rice hispa, rice stem borer, rice bug, which were controlled by spraying Diazinon pillersuphan, Darsban, and Malathion. Irrigations were also done as and when necessary.

3.1.11 Plant sampling at harvest

Plants from 1 m² were randomly selected from each plot to record the yield contributing characters like plant height (cm), number of tillers hill⁻¹, panicle length (cm), number of grains panicle⁻¹, and 1000-grain weight (g). The selected hills were collected before harvesting. Grain and straw yields were recorded plot-wise and expressed at t ha⁻¹ on sun dry basis.

3.1.12 Harvesting

The crop was harvested at maturity on 2 December, 2012. The harvested crop was threshed plot-wise. Grain and straw yields were recorded separately plot-wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw were also recorded.

3.1.13 Data collection

The data on the following growth and yield contributing characters of the crop were recorded:

- i) Plant height (cm)
- ii) Number of effective and ineffective tillers hill⁻¹
- iii) Panicle length (cm)
- iv) Number of unfilled and filled grains panicle⁻¹
- v) 1000-grain weight (g)
- vi) Grain and straw yields (t ha⁻¹)

3.1.13.1 Plant height (cm)

The plant height was measured from the ground level to the top of the panicle. Plants of 10 hills (1 m²) were measured and average for each plot.

3.1.13.2 Number of tillers hill⁻¹

Ten hills were taken at random from each plot and the number of tillers hill⁻¹ were counted. The numbers of effective and uneffective tillers hill⁻¹ were also determined.

3.1.13.3 Panicle length

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

3.1.13.4 Filled and unfilled grains panicle⁻¹

Ten panicles were taken at random to count unfilled and filled grains and averaged.

3.1.13.5 1000-grain weight

The weight of 1000-grains from each plot was taken after sun drying by an electric balance.

3.1.13.6 Grain and straw yields

Grain and straw yields were recorded separately plot-wise and expressed as $t\ ha^{-1}$ on 14% moisture basis.

3.1.14 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of Soil Resource Development Institute (SRDI), Farmgate, Dhaka. The properties studied included soil texture, pH, organic matter, total N, available P, exchangeable K and available S. The physical and chemical properties of the initial soil have been presented in Table 2. The soil was analyzed by standard methods:

3.1.14.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method (Bouyoucos, 1926) and the textural class was determined by plotting the values for % sand, % silt and % clay to the “Marshall’s Textural Triangular Coordinate” according to the USDA system.

3.1.14.2 Soil pH

Soil pH was measured with the help of a Glass electrode pH meter using soil and water at the ratio of 1:2.5 as described by Jackson (1962).

3.1.14.3 Organic carbon

Organic carbon in soil was determined by Walkley and Black (1934) Wet Oxidation Method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution.

To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

3.1.14.4 Total nitrogen

Total nitrogen of soil was determined by Micro Kjeldahl method where soil was digested with 30% H₂O₂, conc. H₂SO₄ and catalyst mixture (K₂SO₄: CuSO₄.5H₂O: Se powder in the ratio of 100:10:1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H₃BO₃ with 0.01N H₂SO₄ (Bremner and Mulvaney, 1982).

3.1.14.5 Available phosphorus

Available phosphorus was extracted from soil by shaking with 0.5 M NaHCO₃ solution of pH 8.5 (Olsen *et al.*, 1954). The phosphorus in the extract was then determined by developing blue colour using SnCl₂ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 nm wave length by Spectrophotometer and available P was calculated with the help of standard curve.

3.1.14.6 Exchangeable potassium

Exchangeable potassium was determined by 1N NH₄OAc (pH 7.0) extract of the soil by using Flame photometer (Black, 1965).

3.1.14.7 Available sulphur

Available sulphur in soil was determined by extracting the soil samples with 0.15% CaCl₂ solution (Page *et al.*, 1982) The S content in the extract was determined turbidmetrically and the intensity of turbid was measured by Spectrophotometer at 420 nm wave length.

3.1.15 Chemical analysis of plant samples

3.1.15.1 Preparation of plant samples

Ten selected hills plot⁻¹ were collected immediately after harvest of the crop. The selected hills were threshed. Both grain and straw were cleaned and dried in an oven at 65⁰C for 48 hours. The dried samples were grinded and put into small paper bags and kept into a desiccators till being used.

3.1.15.2 Digestion of plant samples with sulphuric acid

For N determination, an amount of 0.1 g plant sample (grain/straw) was taken into a 100 ml Kjeldahl flask. An amount of 1.1 g catalyst mixture (K₂SO₄: CuSO₄. 5H₂O: Se = 100:10:1), 2 ml 30% H₂O₂ and 3 ml conc. H₂SO₄ were added into the flask. The flask was swirled and allowed to stand for about 10 minutes, followed by heating at 200⁰C. Heating was continued until the digest was clear, and colorless. After cooling, the contents were taken into a 100 ml volumetric flask and the volume was made with distilled water. A blank digestion was prepared in a similar way except plant sample. This digest was used for determining the nitrogen contents on plant samples.

3.1.15.3 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5 g of plant sample was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO₃, HClO₄ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature raising slowly to 200⁰C. Heating was instantly stopped as soon as the dense white fumes of HClO₄ occurred and after cooling, 6 ml of 6N HCl were added to it. The content of the flask was boiled until they become clear and colourless. This digest was used for determining P, K, S and Zn.

3.1.16 Statistical Analysis

The statistical analysis for different character including the nutrient content and uptake were done following the ANOVA technique and the mean results in case of significant F-values were adjusted by the Duncan's Multiple Range Test (DMRT).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the experiment conducted under field conditions are presented in several Tables and Figures. The experiment was conducted to study the effect of integrated nutrient management on the growth and yield of NERICA 10. The results are presented and discussed under the following parameters.

4.1 Growth and yield components

4.1.1 Plant height

Plant height of NERICA 10 was significantly influenced by cowdung, vermicompost and inorganic nitrogenous fertilizers (Table 4). All the treatment was recorded significantly higher plant height over the control (T₁ treatment). Plant height ranged from 93.21 to 100.3 cm. The tallest plant of 100.3 cm was found in T₅ receiving 80 kg N as a source of urea. However, plant height recorded either with single or combined application of nitrogen and manure or vermicompost was higher than that of control treatment. The shortest plant height of 93.21 cm was found in T₁ (control) treatment having no cowdung or vermicompost even any chemical fertilizer. Treatment T₅ receiving 80 kg N from urea and 40 kg N from vermicompost produced 7.60% higher plant height compared to control treatment (Fig.3). The treatments may be ranked in the order of T₅> T₂> T₁₀> T₁₁> T₉> T₈> T₆> T₇>T₄> T₃> T₁ treatments. Haque (1999) found that plant height significantly increased with the application of cowdung along with chemical fertilizer. The increased plant height through the application of FYM along with N, P, K and S was also reported by many other scientist (Kobayashi *et al.*, 1989; Maskina *et al.*, 1987). Mostofa *et al.* (2009) observed that the yield contributing characters like plant height was the highest in 100 kg ha⁻¹ of K.

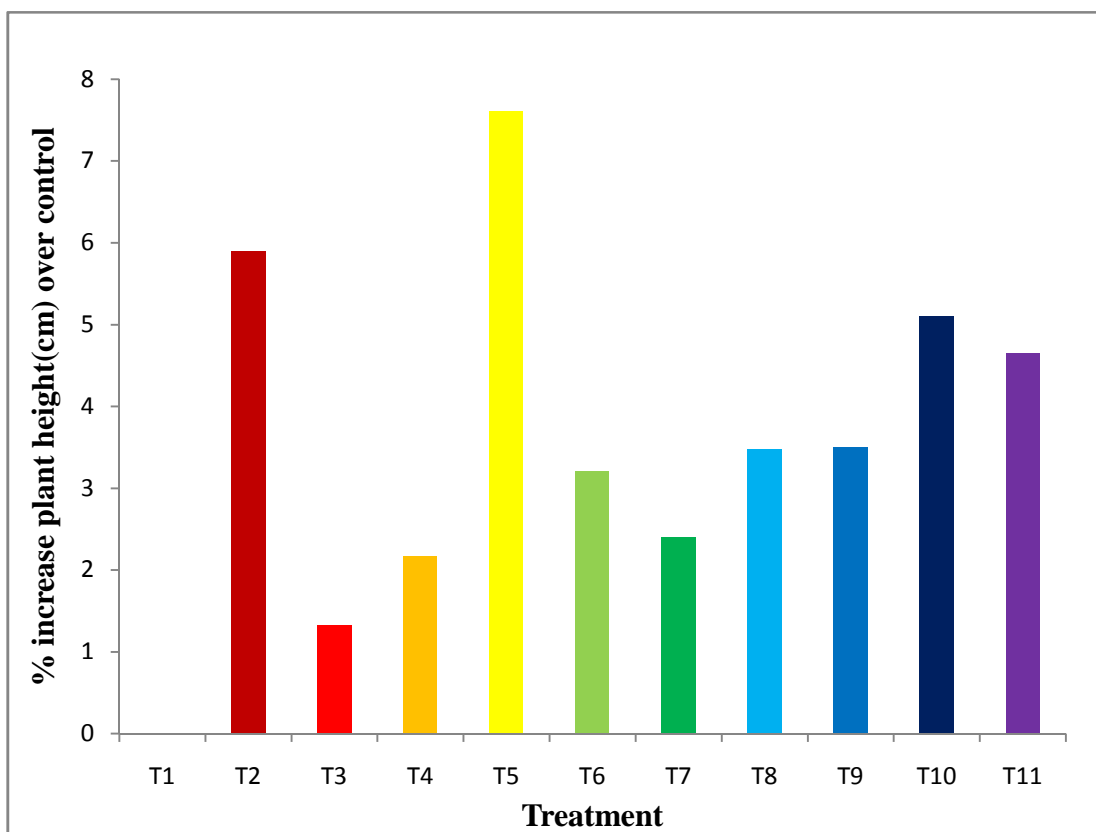


Fig. 3 . Effect of Integrated Nutrient Management on percent increase plant height over control of NERICA 10

4.1.2 Panicle length

The effects of different treatments on panicle length are shown in Table 4. The tallest panicle length (21.34 cm) was found in T₁₀ treatment which was statistically identical with T₂, T₄, T₆, T₇, T₉ and T₁₁ treatments. The shortest panicle (19.32 cm) was observed in T₁ (control). The treatments may be ranked in the order of T₁₀> T₂> T₄>T₇> T₉> T₁₁> T₆>T₃>T₅> T₈> T₁ in terms of panicle length. Morteza *et al.* (2011) also observed that the panicle length was increased with the application of inorganic fertilizers and manures. Krishnappa *et al.* (2006) reported that increasing K rates increased panicle length. Treatment T₁₀ produced 10.45% higher panicle length than control treatment (Fig. 4).

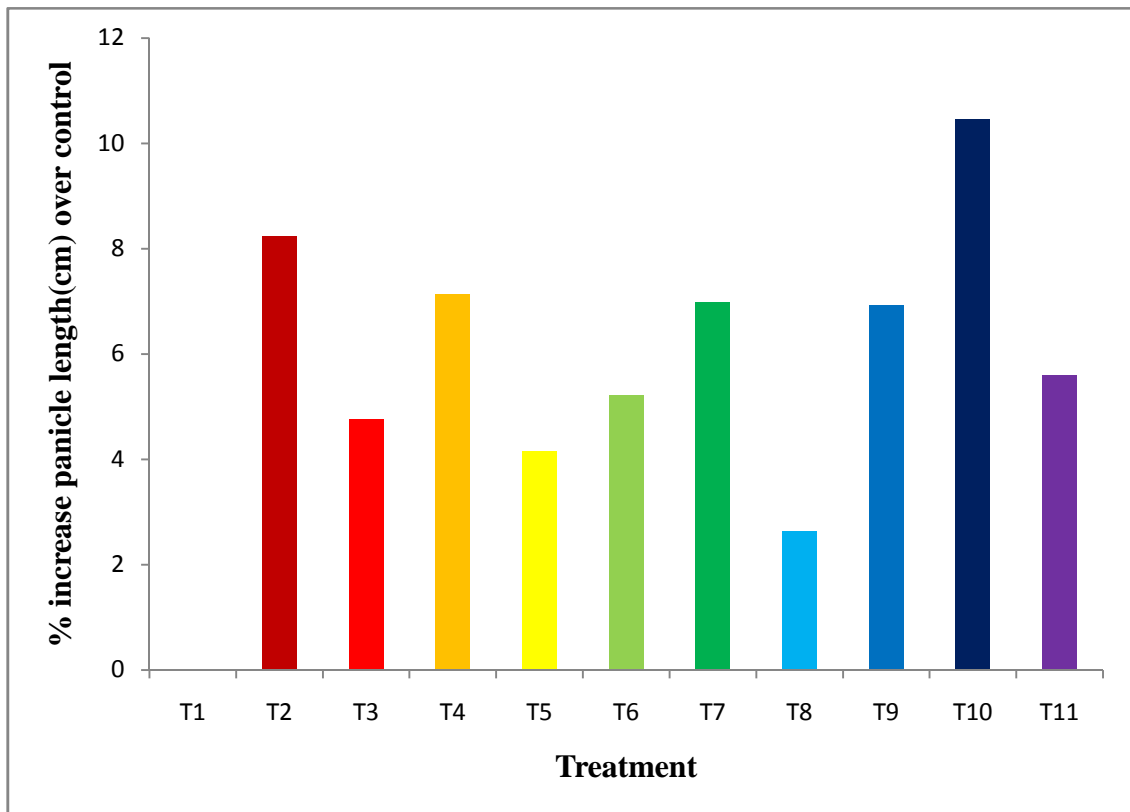


Fig. 4. Effect of Integrated Nutrient Management on percent increase panicle length over control of NERICA 10

4.1.3 Effective tillers hill⁻¹

There was a significant effect of the treatments on number of effective tiller per hill (Table 4). All the treatments significantly produced higher number of effective tiller per hill over control (T₁ treatment). The effective tiller per hill ranges from 8.3 to 12.9. The highest number of effective tiller hill⁻¹ (12.9) was found in T₁₀ receiving 40 kg N as a source of urea and 80 kg N from cowdung and the lowest was found in T₁ (8.3) treatment. The treatments may be ranked in the order of T₁₀> T₉> T₈>T₇> T₅> T₆> T₄>T₃>T₂> T₁₁> T₁ in terms of effective tiller hill⁻¹ (Fig: 5). These results were corroborated with the findings of Uddin *et al.* (2009) who found increased number of effective tiller hill⁻¹ with the integrated use of manures and fertilizers. Treatment T₁₀ produced 55.42% higher number of effective tiller per hill than control treatment (Fig. 5).

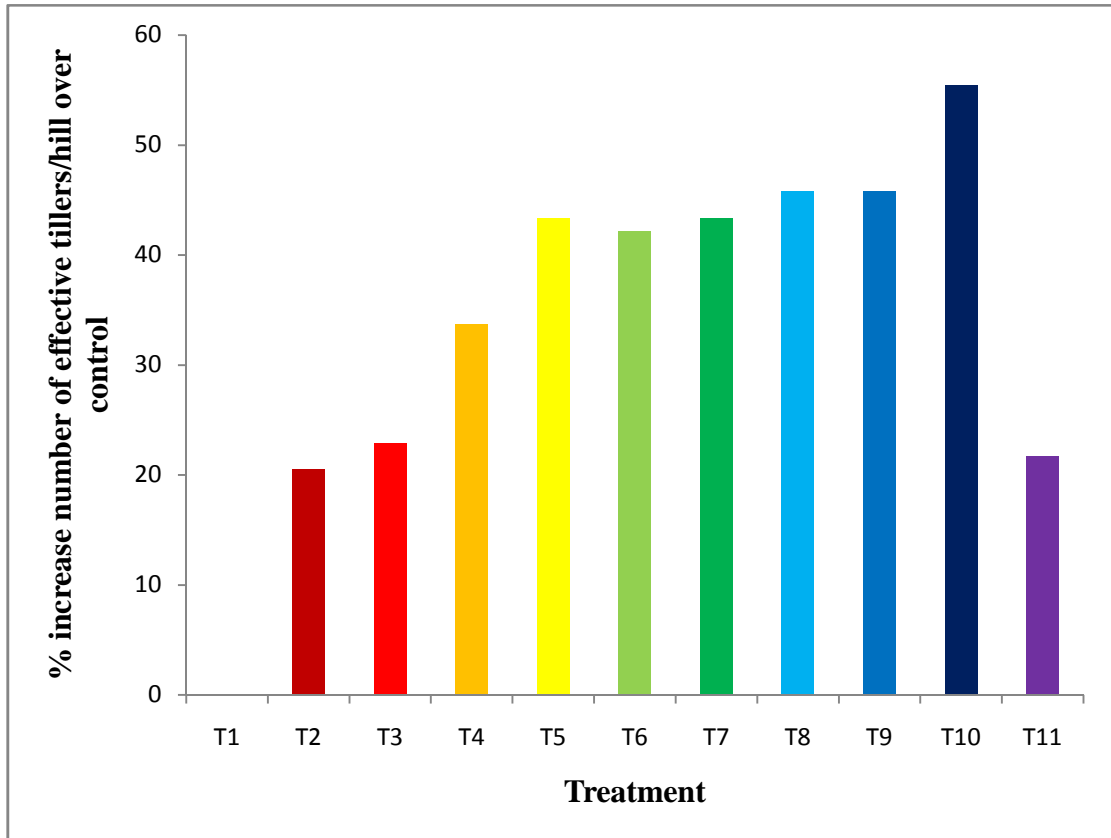


Fig. 5. Effect of Integrated Nutrient Management on percent increase number of effective tillers hill⁻¹ over control of NERICA 10

4.1.4 Filled grains panicle⁻¹

There was a significant effect of the treatments on number of filled grains per panicle (Table 4). The number of filled grain panicle⁻¹ ranged from 80 to 95. The maximum number of filled grains per panicle (95) was noted when 100 kg N applied from urea and 20 kg from vermicompost. The minimum number of filled grains per panicle (80/panicle) was recorded in T₁ treatment receiving no chemical fertilizer and manure. The treatments may be ranked in the order of T₃>T₁₁>T₆>T₂>T₇>T₈>T₅>T₄>T₁₀>T₉>T₁ with the respect of the number of filled grain panicle⁻¹ (Fig: 6). Wang *et al.* (2011) showed that the application of N, P and K fertilizer significantly increased the number of filled grain panicle⁻¹ and the highest the number of filled grain panicle⁻¹ was found under the combined application of N, P and K fertilizer. Treatment T₁₁ produced 18.75% higher number of filled grains per panicle (Fig. 6).

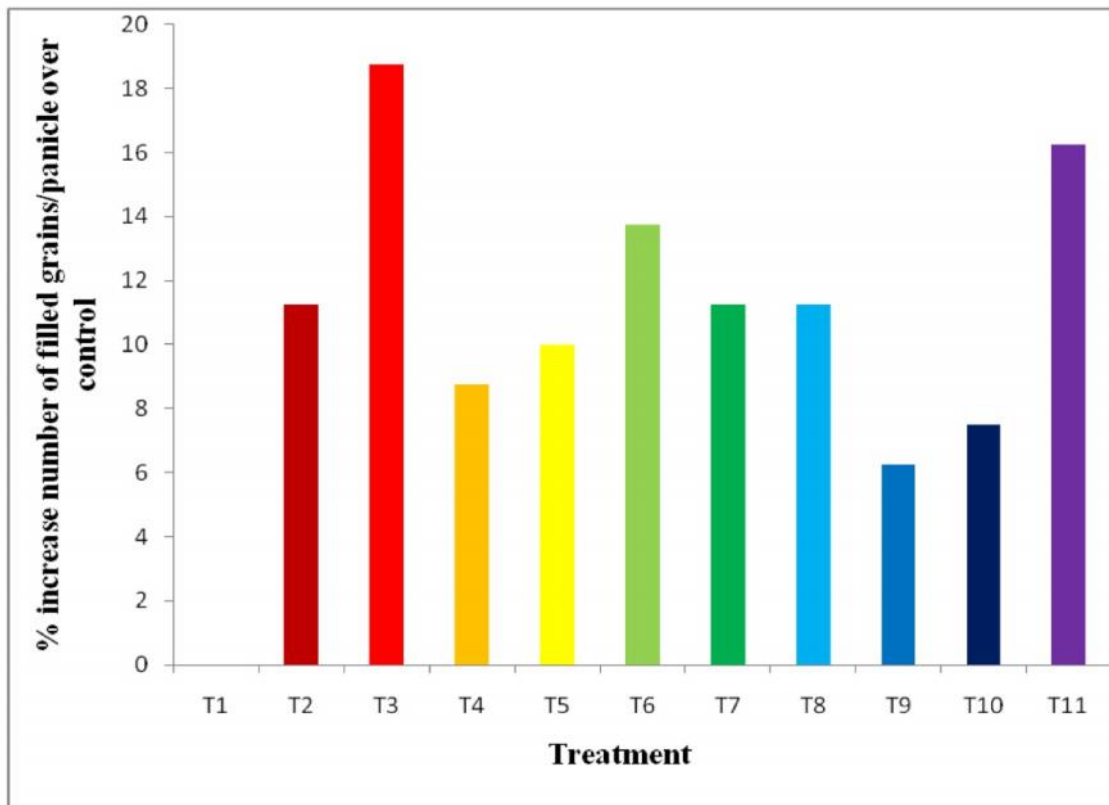


Fig. 6. Effect of Integrated Nutrient Management on percent increase number of filled grains panicle⁻¹ over control of NERICA 10

4.1.5 Unfilled grains panicle⁻¹

The effects of different treatments on number of unfilled grains per panicle are shown in Table 4. The number of unfilled grain per panicle ranged from 29 to 36. The highest number of unfilled grains per panicle (36/panicle) was noted in treatment T₁ (Control). The lowest number of unfilled grains per panicle (29/panicle) was recorded in T₅ treatment receiving 80 kg N from urea and 40 kg N/ha from vermicompost. The treatments may be ranked in the order of T₁>T₄>T₉>T₂> T₁₁>T₆>T₁₀>T₇> T₃>T₈>T₅ with respect of the number of unfilled grains per panicle (Fig: 7). These results were corroborated with the findings of Sarkar and Singh (2002) who found increased the number of filled grains per panicle and decreased the number of unfilled grains per panicle significant increased with the application of N, P, K and S.

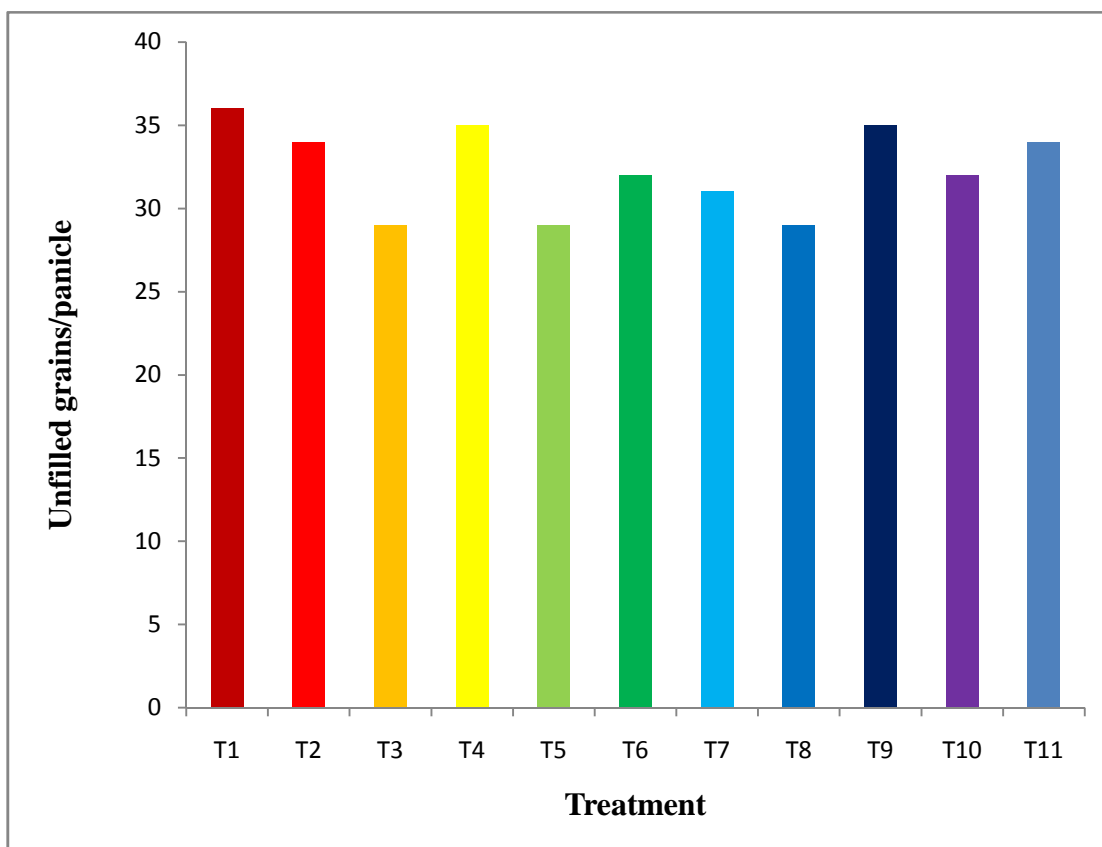


Fig. 7. Effect of Integrated Nutrient Management on number of unfilled grains panicle⁻¹ of NERICA 10

4.1.6 1000-grain weight

A significant difference in 1000-grain weight was observed at different levels of nitrogen along with cowdung and vermicompost (Table 4). The 1000-grain weight ranged from 26 to 32.5 g. The highest weight of 1000-grain weight (32.5 g) observed when 100 kg N applied from urea and 20 kg from vermicompost (T₃ treatment) and the lowest weight of 1000-grain weight (26 g) was observed in T₁ treatment receiving no chemicals or manures. The treatments may be ranked in the order of T₃>T₈>T₉>T₇>T₁₀>T₄>T₆>T₁₁>T₅>T₂ with respect of 1000-grain weight. Debiprasad *et al.* (2010) found that application of 120 kg N ha⁻¹ through chemical fertilizer with the combination of press mud and cowdung increased 1000-grain weight.

Table 4. Effect of Integrated Nutrient Management on plant height, panicle length, effective tillers hill⁻¹, filled grains panicle⁻¹, unfilled grains panicle⁻¹ and 1000-grain weight of NERICA 10.

Treatment	Plant height (cm)	Panicle length (cm)	Effective tillers hill ⁻¹ (no.)	Filled grains panicle ⁻¹ (no.)	Unfilled grains panicle ⁻¹ (no.)	1000-grain weight (g)
T ₁	93.21f	19.32d	8.3e	80e	36a	26f
T ₂	98.71b	20.91ab	10d	89bcd	34abc	26.5ef
T ₃	94.45ef	20.24bcd	10.2d	95a	29d	32.5a
T ₄	95.23de	20.70abc	11.1c	87cd	35ab	29c
T ₅	100.3a	20.12bcd	11.9b	88cd	29d	27de
T ₆	96.20cd	20.33abcd	11.8b	91abc	32bcd	27.5d
T ₇	95.45de	20.67abc	11.9b	89bcd	31cd	30.5b
T ₈	96.45cd	19.83cd	12.1b	89bcd	29d	32a
T ₉	96.47cd	20.66abc	12.1b	85d	35ab	31b
T ₁₀	97.97b	21.34a	12.9a	86d	32bcd	29c
T ₁₁	97.54bc	20.40abc	10.1d	93ab	34abc	27de
LSD _{0.05}	1.445	1.040	0.533	4.364	3.609	0.502
CV (%)	0.88	2.99	2.81	2.90	6.55	1.02

Means in a column followed by same letter(s) are not significantly different at 5% level of significance by LSD.

T₁: No chemical fertilizer, no organic manure (Control)

T₂: 100% recommended N (120 kg nitrogen ha⁻¹) + recommended P,K,S,Zn

T₃: 100 kg N from urea + 20 kg N substituted by vermicompost + recommended P,K,S,Zn

T₄: 100 kg N from urea + 20 kg N substituted by cowdung + recommended P,K,S,Zn

T₅: 80 kg N from urea + 40 kg N substituted by vermicompost + recommended P,K,S,Zn

T₆: 80 kg N from urea + 40 kg N substituted by cowdung + recommended P,K,S,Zn

T₇: 60 kg N from urea + 60 kg N substituted by vermicompost + recommended P,K,S,Zn

T₈: 60 kg N from urea + 60 kg N substituted by cowdung + recommended P,K,S,Zn

T₉: 40 kg N from urea + 80 kg N substituted by vermicompost + recommended P,K,S,Zn

T₁₀: 40 kg N from urea + 80 kg N substituted by cowdung + recommended P,K,S,Zn

T₁₁: 100% N substituted by equal portion of vermicompost and cowdung + recommended P,K,S,Zn

4.2 Yields

4.2.1 Grain yield

The grain yield of NERICA 10 varied significantly due to application of different rates of fertilizer treatments (Table 5). The grain yield ranged from 1.50 to 4.35 t ha⁻¹. The highest grain yield (4.35 t ha⁻¹) was observed in T₃ treatment receiving 100 kg N from urea and 20 kg N substituted by vermicompost. The lowest value (1.50 t ha⁻¹) was recorded in T₁ (control) treatment. The treatment T₃ produced the maximum grain yield than other treatments. Second highest yield (4.20 t ha⁻¹) was found in T₈ treatment receiving 60 kg N from urea which was identical with T₆, T₄, T₁₁, T₉, T₂, T₅ and T₁₀ treatments. The treatments may be ranked in the order of T₃>T₈> T₆>T₄> T₁₁>T₉>T₂>T₅>T₁₀>T₇>T₁ with respect of grain yield. The percent increase in grain yield over control ranged from 133.33 to 190.00% where the maximum increase was recorded in T₃ treatment and the lowest value being noted in T₇ treatment (Fig. 8). Yadav *et al.* (2010) reported that grain yield was significantly increased due to application of chemical fertilizers and residual effects of organic manures.

4.2.2 Straw yield

Straw yield of NERICA 10 also varied significantly by different treatments under study (Table 5). The yields of straw ranged from 2.18 to 5.35 t ha⁻¹. The highest straw yield of 5.35 t ha⁻¹ was obtained in T₃ treatment (100 kg N from urea and 20 kg N substituted by vermicompost) which was statistically differed with other treatments except T₁₀, T₆, T₁₁, T₄ and the lowest value of 2.18 t ha⁻¹ was noted in T₁ (control) treatment. The treatment may be ranked in the order of T₃>T₁₀> T₆>T₁₁>T₄>T₈>T₂>T₇>T₅>T₉>T₁ in terms of straw yield. Regarding the percent increase of straw yield, maximum straw yield increase over control (154.76%) was noted in T₃ treatment and the minimum (104.76%) was found in T₁₁ treatment (Fig. 9). Saha *et al.* (2007) reported that the straw yield was significantly increased due to application of chemical fertilizers and residual effects of organic manures.

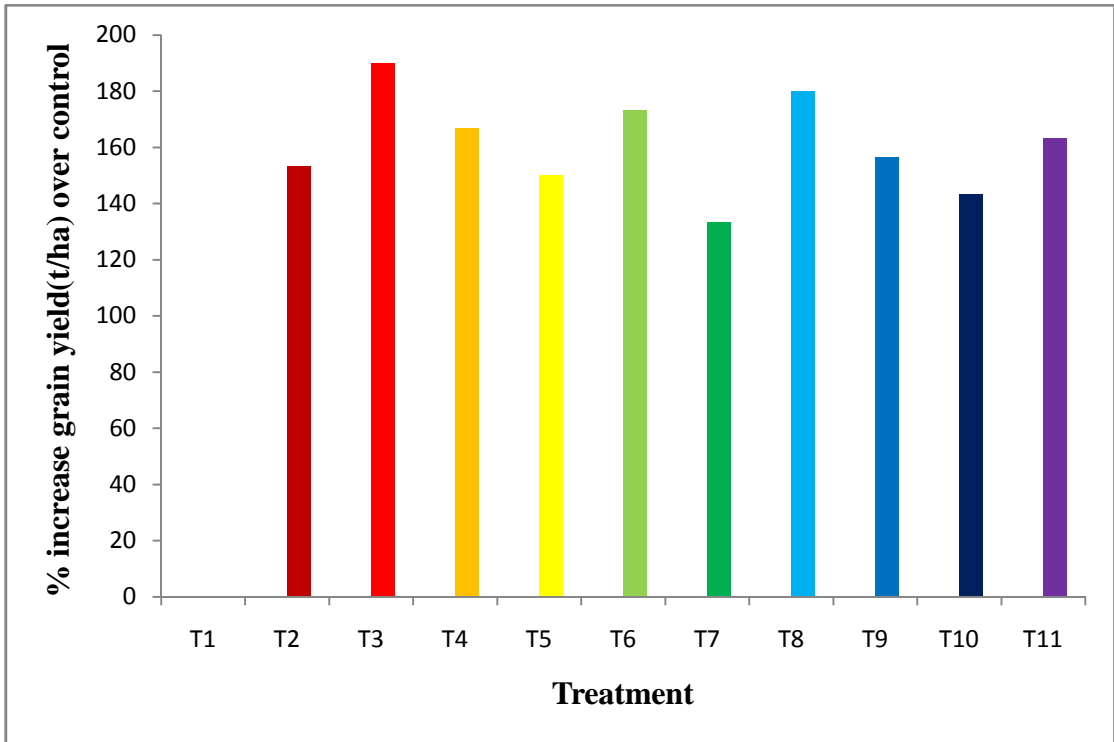


Fig. 8. Effect of Integrated Nutrient Management on percent increase grain yield (t ha⁻¹) over control of NERICA 10 rice crop

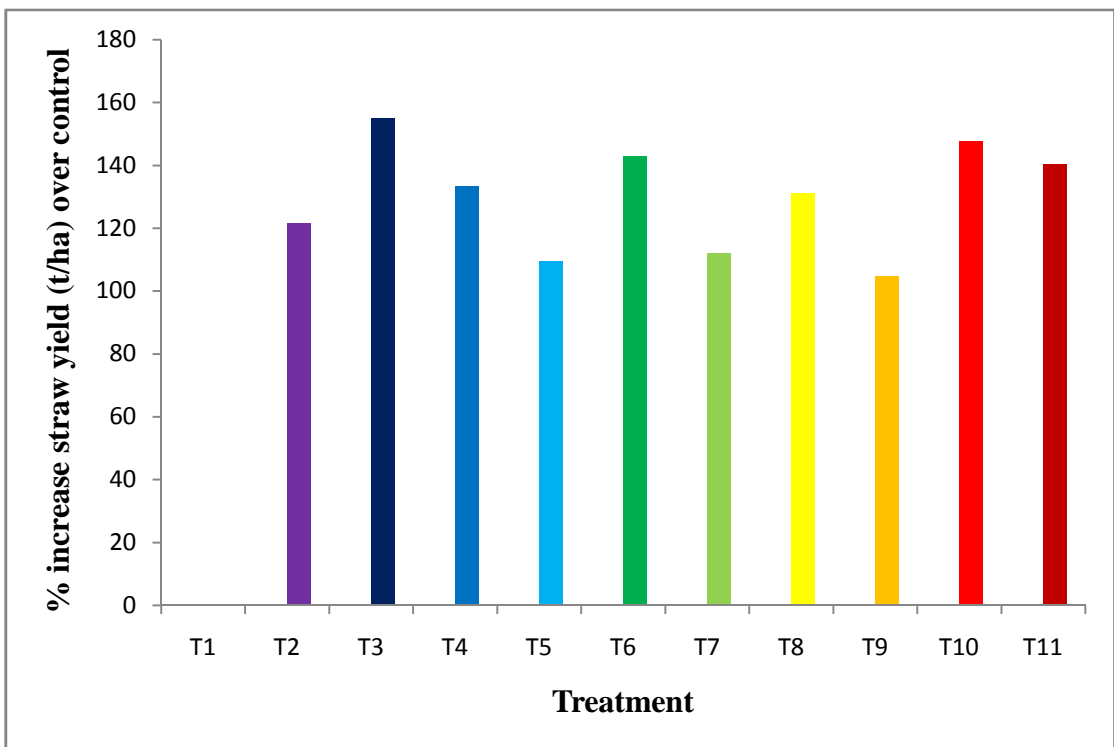


Fig. 9. Effect of Integrated Nutrient Management on percent increase straw yield (t ha⁻¹) over control of NERICA 10 rice crop

Table 5. Effect of Integrated Nutrient Management on the grain and straw yields (t ha⁻¹) of NERICA 10 rice crop

Treatment	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
T ₁	1.50d	2.10g
T ₂	3.80abc	4.65cdef
T ₃	4.35a	5.35a
T ₄	4.00abc	4.90abcd
T ₅	3.75bc	4.40ef
T ₆	4.10ab	5.10abc
T ₇	3.50c	4.45def
T ₈	4.20ab	4.85bcde
T ₉	3.85abc	4.30f
T ₁₀	3.65bc	5.20ab
T ₁₁	3.95abc	5.05abc
LSD _{0.05}	0.557	0.469
CV (%)	8.86	6.02

Means in a column followed by same letter(s) are not significantly different at 5% level of significance by LSD.

T₁: No chemical fertilizer, no organic manure (Control)

T₂: 100% recommended N (120 kg nitrogen ha⁻¹) + recommended P,K,S,Zn

T₃: 100 kg N from urea + 20 kg N substituted by vermicompost + recommended P,K,S,Zn

T₄: 100 kg N from urea + 20 kg N substituted by cowdung + recommended P,K,S,Zn

T₅: 80 kg N from urea + 40 kg N substituted by vermicompost + recommended P,K,S,Zn

T₆: 80 kg N from urea + 40 kg N substituted by cowdung + recommended P,K,S,Zn

T₇: 60 kg N from urea + 60 kg N substituted by vermicompost + recommended P,K,S,Zn

T₈: 60 kg N from urea + 60 kg N substituted by cowdung + recommended P,K,S,Zn

T₉: 40 kg N from urea + 80 kg N substituted by vermicompost + recommended P,K,S,Zn

T₁₀: 40 kg N from urea + 80 kg N substituted by cowdung + recommended P,K,S,Zn

T₁₁: 100% N substituted by equal portion of vermicompost and cowdung + recommended P,K,S,Zn

4.3 Nutrient content in grain and straw

The grain and straw samples of NERICA 10 were analyzed for estimating N, P, K and S content. The results of N, P, K and S contents of grain and straw have been discussed under the following sub-sections.

4.3.1 Nitrogen content

The N content in rice grain varied significantly in different treatments (Table 6). The highest N content of 1.02% was observed in T₃ treatment receiving 100 kg N from urea and 20 kg N substituted by vermicompost. The lowest N content of 0.90% was noted in control (T₁ treatment). The N content in rice grain markedly which was identical with T₆, T₁₀, T₁₁ and T₄ treatments.

In the straw, the N content varied significantly due to different treatments (Table 6). The N content in the straw ranged from 0.39% to 0.57%. The maximum N content in straw (0.57%) was found in T₃ treatment receiving 100 kg N from urea which was statistically similar to T₇ and T₁₁ treatment. Treatment along with chemical nitrogen performed better in recording nitrogen content in straw over other treatments including organic manure even control. This might be due to the application of urea fertilizer which supplied adequate nitrogen produced protein or amino acid which was converted to nitrogen and ultimately increased nitrogen content in straw. The lowest nitrogen content in straw (0.39%) was found in T₁ (control) treatment.

A significant increase in N content in rice grain and straw due to the application of chemical fertilizers and residual effects of organic manures has been reported by Mann *et al.* (2006). Gupta *et al.* (2000) revealed that the combined application of urea and FYM significantly enhanced N content in rice straw and grain.

4.3.2 Phosphorus content

Phosphorus content in grain was varied significantly due to the influence of inorganic and organic fertilizer (Table 6). The P content in grain varied from 0.16% to 0.23%. The highest P content of 0.23% was observed in T₅ treatment which was statistically similar to T₁₁, T₃, T₂, T₄, and T₁₀ treatments in recording P content in grain but superior to the rest of the treatments of NERICA 10. The lowest P content of 0.16% was observed in T₁ treatment.

Phosphorus content in rice straw was influenced significantly due to the integrated effects of organic manures and chemical fertilizers. The highest P content in straw (0.12%) was observed in T₇ treatment which is statistically similar to T₃, T₆, T₉ and T₁₁ treatment. The lowest value (0.090%) was recorded in T₁ treatment.

An increase in P content both in rice grain and straw due to the application of chemical fertilizers and residual effects of organic manures was reported by Indrani *et al.* (2008). Solaiman *et al.* (2011) showed that the P content was significantly increased where urea, cowdung, poultry manure and urban wastes are applied together.

4.3.3 Potassium content

Potassium content in grain was varied significantly due to the influence of inorganic and organic fertilizer (Table 6). The K content in rice grain ranged from 0.15 to 0.24%. The highest K content of 0.24% was observed in T₃ treatment which was statistically similar to T₄, T₆, T₇, T₈, and T₁₀ treatments. This might be due to the application cowdung along with urea fertilizer which supplied sufficient K for growth and development of crop resulting increase in K content in grain. The lowest K content of 0.15% was observed in T₁ treatment.

Potassium content in rice straw was influenced significantly due to the integrated effects of organic manures chemical fertilizers. The highest K content in straw (1.47%) was observed in T₉ treatment which is statistically similar to T₃, T₁₀, T₆, T₁₁, T₈ and T₅ treatments. The lowest value (1.27%) was recorded in T₁ (control).

These results are in agreement with Krishnappa *et al.* (2006) who revealed that K content in grain and straw were increased due to application of chemical fertilizers and residual effects of organic manures. Shen *et al.* (2003) found that K content in grain and straw were increased due to combined application of chemical fertilizers and organic manures.

4.3.4 Sulphur content

Sulphur content in grain was varied significantly due to the influence of inorganic and organic fertilizer (Table 6). The S content in rice grain ranged from 0.09 to 0.35%. The highest K content of 0.35% was observed in T₇ treatment which was statistically similar to T₆, T₄, T₁₁ and T₈ treatments. The lowest K content of 0.09% was observed in T₁ treatment.

In case of straw, the highest S content (0.12%) was obtained in T₁₁ treatment and the lowest value (0.08%) was noted in T₁ (control) treatment. Sulphur content varied insignificantly due to application of manures and fertilizers.

Mann *et al.* (2006) reported that application of chemical fertilizers and residual effects of organic manures increased the S content both in grain and straw of rice. Bhuvanewari *et al.* (2007) showed that sulphur use efficiency was highest and sulphur content was higher in the presence of organic fertilizers.

Table 6: Effects of integrated nutrient management on N, P, K and S content (%) of NERICA 10 rice crop

Treatment	Grain				Straw			
	N	P	K	S	N	P	K	S
T ₁	0.90c	0.16e	0.15d	0.09b	0.39c	0.09c	1.27c	0.08c
T ₂	0.93bc	0.21bc	0.17bcd	0.10b	0.51abc	0.10bc	1.34bc	0.09bc
T ₃	1.02a	0.22ab	0.24a	0.09b	0.57a	0.12a	1.46a	0.08c
T ₄	0.96abc	0.21bc	0.22ab	0.11ab	0.52abc	0.10bc	1.35bc	0.09bc
T ₅	0.90c	0.23a	0.15d	0.10b	0.48abc	0.09c	1.37abc	0.08c
T ₆	1.00ab	0.18d	0.21abc	0.11ab	0.46abc	0.11ab	1.42ab	0.080c
T ₇	0.93bc	0.17de	0.21abc	0.35a	0.56a	0.12a	1.34bc	0.08c
T ₈	0.93bc	0.17de	0.20a-d	0.12ab	0.48abc	0.09c	1.38ab	0.10b
T ₉	0.93bc	0.17de	0.17bcd	0.09b	0.41bc	0.11ab	1.47a	0.09bc
T ₁₀	1.00ab	0.20c	0.19a-d	0.10b	0.53ab	0.10bc	1.43ab	0.08c
T ₁₁	0.97abc	0.22ab	0.16cd	0.11ab	0.56a	0.11ab	1.38ab	0.12a
LSD _{0.05}	0.076	0.170	0.054	0.247	0.131	0.170	0.107	0.170
CV(%)	4.59	10.09	12.82	116.78	15.39	14.31	4.84	22.11

Means in a column followed by same letter(s) are not significantly different at 5% level of significance by LSD.

T₁: No chemical fertilizer, no organic manure (Control)

T₂: 100% recommended N (120 kg nitrogen ha⁻¹) + recommended P,K,S,Zn

T₃: 100 kg N from urea + 20 kg N substituted by vermicompost + recommended P,K,S,Zn

T₄: 100 kg N from urea + 20 kg N substituted by cowdung + recommended P,K,S,Zn

T₅: 80 kg N from urea + 40 kg N substituted by vermicompost + recommended P,K,S,Zn

T₆: 80 kg N from urea + 40 kg N substituted by cowdung + recommended P,K,S,Zn

T₇: 60 kg N from urea + 60 kg N substituted by vermicompost + recommended P,K,S,Zn

T₈: 60 kg N from urea + 60 kg N substituted by cowdung + recommended T₁: P,K,S,Zn

T₉: 40 kg N from urea + 80 kg N substituted by vermicompost + recommended P,K,S,Zn

T₁₀: 40 kg N from urea + 80 kg N substituted by cowdung + recommended P,K,S,Zn

T₁₁: 100% N substituted by equal portion of vermicompost and cowdung + recommended P,K,S,Zn

4.4 Nutrient uptake

The results of N, P, K and S uptake by grain and straw of NERICA 10 have been presented and discussed below:

4.4.1 Nitrogen uptake

Nitrogen uptake by grain was significantly influenced by the application of different levels of cowdung and vermicompost along with chemical nitrogenous fertilizer (Table 7). The N uptake by grain ranged from 14.55 to 43.50 kg ha⁻¹. The highest N uptake by grain (43.50 kg ha⁻¹) observed in T₃ treatment receiving 100 kg N from urea and 20 kg N from vermicompost which was statistically superior to the rest of the treatments which is identical with T₆ and T₈ treatment. The lowest N uptake by grain (14.55 kg ha⁻¹) observed in T₁ (control) treatment.

Nitrogen fertilizer along with cowdung and vermicompost significantly increased N uptake by straw (Table 7). The maximum N uptake of 29.96 kg ha⁻¹ by straw was noted in T₃ treatment which is identical with T₁₁, T₁₀, T₄, T₇, T₂ and T₁₁ treatment. The lowest N uptake by straw (8.50 kg ha⁻¹) observed in T₁ (control) treatment.

Jacqueline *et al.* (2008) reported that the N uptake by rice grain and straw increased significantly with the combined application of organic manure and chemical fertilizers. Vennila (2007) reported that 75% recommended dose of N fertilizer + 25% N as poultry manure increased N uptake in rice. Sarfaraz *et al.* (2002) found that NPK concentrations and their uptake in grain and straw significantly increased with the application of NPK + S fertilizers compared to the control.

4.4.2 Phosphorus uptake

Phosphorous uptake by grain was significantly influenced by the application of different levels of cowdung and vermicompost along with chemical nitrogenous

fertilizer (Table 7). The P uptake by grain ranged from 2.7 to 8.7 kg ha⁻¹. The highest P uptake by grain (8.7 kg ha⁻¹) observed in T₃ treatment receiving 100 kg N from urea and 20 kg N from vermicompost which is identical with T₁₁, T₅, T₄, T₃ and T₂ treatment. The lowest P uptake by grain (2.7 kg ha⁻¹) observed in T₁ (control) treatment.

Effect of cowdung and vermicompost along with nitrogen fertilizer on phosphorous uptake by straw was significant (Table 7). The P uptake by straw ranged from 2.19 to 6.06 kg ha⁻¹. The highest P uptake by straw (6.06 kg ha⁻¹) observed in T₃ treatment which is identical with T₁₁, T₆, T₇ and T₁₀ treatment. The lowest P uptake by straw (2.19 kg ha⁻¹) observed in T₁ (control) treatment.

Moula (2005) reported that nutrient content as well as nutrient uptake by rice over other treatments due to combined application of organic and inorganic fertilizers. Zhang *et al.* (1998) reported that organic manures increased labile, moderately stable and stable organic P contents in soil and uptake by plants.

4.4.3 Potassium uptake

A significant variation in potassium uptake by grain was observed due to the application of different levels of nitrogenous fertilizer along with organic manures (Table 7). The K uptake by grain ranged from 3.15 to 8.80 kg ha⁻¹. The highest K uptake by grain (8.80 kg ha⁻¹) observed in T₄ treatment which is identical with T₃, T₈, T₁₀ and T₇ treatment. The lowest K uptake by grain (3.15 kg ha⁻¹) observed in T₁ (control) treatment.

Effect of cowdung and vermicompost along with nitrogen fertilizer on phosphorous uptake by straw was significant (Table 7). The K uptake by straw ranged from 27.84 to 74.28 kg ha⁻¹. The highest K uptake by straw (74.28 kg ha⁻¹) observed in T₃ treatment which is identical with T₁₀, T₁₁, T₆ and T₈ treatment. The lowest K uptake by straw (27.84 kg ha⁻¹) observed in T₁ (control) treatment.

It was found that the K uptake by grain was much lesser than that by straw. The results are in agreement with Sreelatha *et al.* (2006) who reported that application of

organic manure and chemical fertilizers significantly increased the K uptake by rice.

4.4.4 Sulphur uptake

Sulphur uptake by grain was significantly influenced by the application of different levels of cowdung and vermicompost along with chemical nitrogenous fertilizer (Table 7). The S uptake by grain ranged from 1.65 to 5.04 kg ha⁻¹. The highest S uptake by grain (5.04 kg ha⁻¹) observed in T₃ treatment and the lowest S uptake by grain (1.65 kg ha⁻¹) observed in T₁ (control) treatment.

Effect of cowdung and vermicompost along with nitrogen fertilizer on phosphorous uptake by straw was significant (Table 7). The S uptake by straw ranged from 1.74 to 6.42 kg ha⁻¹. The highest S uptake by straw (6.42 kg ha⁻¹) observed in T₃ treatment. The lowest S uptake by straw (1.74 kg ha⁻¹) observed in T₁ (control) treatment.

Bhuvaneswari and Chandrasekharan (2006) observed that application of organic manure and chemical fertilizers increased the sulphur uptake significantly by rice. Azmi *et al.* (2004) found increasing fertility levels significantly increased the crop yield and S uptake.

Table 7: Effect of integrated nutrient management on N, P, K and S uptake (kg ha⁻¹) by NERICA 10 rice crop

Treatment	Grain				Straw			
	N	P	K	S	N	P	K	S
T ₁	14.55f	2.7e	3.15d	1.65h	8.50e	2.19f	27.68d	1.74c
T ₂	35.34cde	7.98ab	6.46bc	3.80de	23.71a-d	4.65b-e	62.31c	4.18b
T ₃	43.50a	8.7a	8.76a	5.04a	29.96a	6.06a	74.36a	6.42a
T ₄	38.40bcd	8.4a	8.80a	4.42b	25.48abc	4.41cde	66.15bc	4.41b
T ₅	33.75de	8.625a	5.62c	3.75e	21.12cd	3.96e	60.28c	3.52b
T ₆	41.00ab	6.56cd	6.15bc	3.69e	23.46a-d	5.61abc	72.42ab	4.08b
T ₇	32.55e	5.95d	7.35ab	2.80g	24.92abc	5.34a-d	59.63c	3.56b
T ₈	39.06abc	7.14bc	8.40a	3.28f	23.28bcd	4.36de	66.93abc	4.85b
T ₉	35.80cde	6.54cd	6.54bc	3.46ef	17.63d	4.73b-e	63.21c	3.87b
T ₁₀	37.23bde	8.03a	8.26a	4.35c	27.56abc	5.20a-d	74.08a	4.16b
T ₁₁	35.55cde	8.69a	6.32bc	4.34c	28.78ab	5.88ab	73.83ab	4.04b
LSD _{0.05}	5.062	0.880	1.696	0.331	6.533	1.239	7.818	1.410
CV(%)	8.45	7.16	14.44	5.01	16.59	15.27	7.20	20.30

Mean in a column followed by same letter(s) are not significantly different at 5% level of significance by LSD.

T₁: No chemical fertilizer, no organic manure (Control)

T₂: 100% recommended N (120 kg nitrogen ha⁻¹) + recommended P,K,S,Zn

T₃: 100 kg N from urea + 20 kg N substituted by vermicompost + recommended P,K,S,Zn

T₄: 100 kg N from urea + 20 kg N substituted by cowdung + recommended P,K,S,Zn

T₅: 80 kg N from urea + 40 kg N substituted by vermicompost + recommended P,K,S,Zn

T₆: 80 kg N from urea + 40 kg N substituted by cowdung + recommended P,K,S,Zn

T₇: 60 kg N from urea + 60 kg N substituted by vermicompost + recommended P,K,S,Zn

T₈: 60 kg N from urea + 60 kg N substituted by cowdung + recommended P,K,S,Zn

T₉: 40 kg N from urea + 80 kg N substituted by vermicompost + recommended P,K,S,Zn

T₁₀: 40 kg N from urea + 80 kg N substituted by cowdung + recommended P,K,S,Zn

T₁₁: 100% N substituted by equal portion of vermicompost and cowdung + recommended P,K,S,Zn

4.5 Nutrient content in post harvest soil

4.5.1 Total nitrogen

The combined effect of different levels of cowdung and vermicompost with the association chemical nitrogenous fertilizer on total nitrogen of post harvest soil was significant (Table 8). The highest total nitrogen of post harvest soil (0.08%) was recorded in T₆ treatment through the application of 80 kg N from urea and 40 kg N substituted by cowdung. It was statistically similar with T₄, T₈ and T₉ treatment but superior to the rest of the treatment of post harvest soil. The lowest total nitrogen of post harvest soil (0.06%) was recorded in T₁ (control) treatment.

4.5.2 Available phosphorous

A significant difference in available phosphorous content of post harvest soil was observed at different levels of cowdung and vermicompost along with nitrogenous fertilizer as the source of urea (Table 8). The highest available P (19.91 ppm) in the post harvest soil was recorded in T₆ treatment and the lowest available P (15.23 ppm) was noted in T₁ (control) treatment.

4.5.3 Exchangeable potassium

There was significant difference among the treatments in recording exchangeable potassium content of post harvest soil (Table 8). The maximum exchangeable potassium of post harvest soil (0.157 meq/100g soil) was found in T₆ treatment which is statistically superior to the rest of the treatment under study. The lowest available K (0.112 meq/100g soil) was noted in T₁ (control) treatment.

4.5.4 Available sulphur

A significant difference in available sulphur content of post harvest soil was observed at different levels of cowdung and vermicompost along with nitrogenous fertilizer as the source of urea (Table 8). The highest available S (30.86 ppm) in the post harvest

soil was recorded in T₇ treatment and the lowest available S (19.11 ppm) was noted in T₁ (control) treatment.

Table 8. Effect of integrated nutrient management on N, P, K and S content in post harvest soil of NERICA 10 rice crop

Treatment	Total N (%)	Available P (ppm)	Exchangeable K (meq/100g soil)	Available S (ppm)
T ₁	0.06c	15.23e	0.112d	19.11i
T ₂	0.07b	16.46d	0.134c	21.6h
T ₃	0.07b	18.97ab	0.142b	22.09g
T ₄	0.08a	17.03d	0.141b	22.57f
T ₅	0.07b	18.52b	0.149b	26.12e
T ₆	0.08a	19.91a	0.157a	28.97d
T ₇	0.07b	18.23bc	0.142b	30.86a
T ₈	0.08a	18.42b	0.148b	29.49c
T ₉	0.08a	17.29cd	0.149b	30.27b
T ₁₀	0.07b	18.62b	0.147b	30.12b
T ₁₁	0.07b	17.14cd	0.139c	29.94bc
LSD _{0.05}	0.17	1.096	0.17	0.45
CV (%)	14.36	3.61	5.12	1.00

Mean in a column followed by same letter(s) are not significantly different at 5% level of significance by LSD.

T₁: No chemical fertilizer, no organic manure (Control)

T₂: 100% recommended N (120 kg nitrogen ha⁻¹) + recommended P,K,S,Zn

T₃: 100 kg N from urea + 20 kg N substituted by vermicompost + recommended P,K,S,Zn

T₄: 100 kg N from urea + 20 kg N substituted by cowdung + recommended P,K,S,Zn

T₅: 80 kg N from urea + 40 kg N substituted by vermicompost + recommended P,K,S,Zn

T₆: 80 kg N from urea + 40 kg N substituted by cowdung + recommended P,K,S,Zn

T₇: 60 kg N from urea + 60 kg N substituted by vermicompost + recommended P,K,S,Zn

T₈: 60 kg N from urea + 60 kg N substituted by cowdung + recommended T₁: P,K,S,Zn

T₉: 40 kg N from urea + 80 kg N substituted by vermicompost + recommended P,K,S,Zn

T₁₀: 40 kg N from urea + 80 kg N substituted by cowdung + recommended P,K,S,Zn

T₁₁: 100% N substituted by equal portion of vermicompost and cowdung + recommended P,K,S,Zn

CHAPTER V

SUMMARY

To evaluate the effects of integrated nutrient management of cowdung and vermicompost along with nitrogen as the source of urea were conducted in late T-Aman season during the period from August 14, 2012 to December 02, 2012 at the research farm of Sher-e-Bangla Agricultural University, Dhaka-1207.

The experiment was carried out to assess the integrated nutrient management on NERICA 10 in late T-Aman season.

The results of the experiment revealed that yield and yield contributing characters and nutrients content and uptake by rice were increased due to the application of varied levels of cowdung and vermicompost along with nitrogen from urea. However, combined application of cowdung and nitrogen at the rate of 100 kg N from urea along with 20 kg N as the source of vermicompost (T₃ treatment) performed best in recording yield and yield contributing characters and nutrients content and uptake by grain and straw of NERICA 10 RICE CROP.

In post harvest soil total nitrogen, available phosphorus, exchangeable potassium and available sulphur were increased due to application of cowdung and vermicompost as compared to initial soil. Fertilized with urea-nitrogen alone decreased the values of organic matter, total nitrogen, available phosphorus, exchangeable potassium and available sulphur in post harvest soil.

The maximum plant height and unfilled grain panicle⁻¹ was recorded in T₅ (80 kg N from urea + 40 kg N from vermicompost) treatment, highest panicle length and effective tillers hill⁻¹ was recorded in T₁₀ (40 kg N from urea + 80 kg N from cowdung) treatment, maximum filled grain panicle⁻¹ and 1000-grain weight was recorded in T₁₁ (100% N from equal portion of cowdung and vermicompost) treatment.

The maximum grain and straw yield of NERICA 10 was recorded in T₃ (100 kg N from urea + 20 kg N from vermicompost) treatment.

In case of nutrient content in grain, the highest N and K content was found in T₃ (100 kg N from urea + 20 kg N from vermicompost) treatment, and the highest P and S content was recorded in T₅ (80 kg N from urea + 40 kg N from vermicompost) and T₇ (60 kg N from urea + 60 kg N from vermicompost) treatment respectively. In straw, the highest N content was found in T₃ (100 kg N from urea + 20 kg N from vermicompost) treatment, P content in T₇ (60 kg N from urea + 60 kg N from vermicompost) treatment, K content in T₉ (40 kg N from urea + 80 kg N from vermicompost) treatment and S content in T₁₁ (100% N from equal portion of cowdung and vermicompost) treatment.

In case of nutrient uptake in grain, the highest N and P content was found in T₁₀ (40 kg N from urea + 80 kg N from cowdung) treatment, and the highest K and S content was recorded in T₄ (100 kg N from urea + 20 kg N from cowdung) and T₈ (60 kg N from urea + 60 kg N from cowdung) treatment. In straw, the highest N and S content was found in T₁₁ (100% N from equal portion of cowdung and vermicompost) treatment, P content in T₃ (100 kg N from urea + 20 kg N from vermicompost) treatment, K content in T₁₀ (40 kg N from urea + 80 kg N from cowdung) treatment.

CONCLUSION

Total time required from sowing to harvesting of NERICA 10 rice crop was 108 days in late T-Aman season. So, farmers can easily cultivate boro rice after harvesting of NERICA 10 RICE CROP.

From the present study finally it can be concluded that the organic manures (cowdung and vermicompost) along with nitrogenous fertilizer had varying degree of integrated effects on NERICA 10 rice crop. Combined application of 100 kg N as the source of urea along with 20 kg N as the source of vermicompost performed the best in recording yield and yield contributing characters of NERICA 10 RICE CROP. Among the organic sources, vermicompost performed the best in recording yield and yield attributing characters as well as NPKS content and uptake by NERICA 10 RICE CROP. Nitrogen, Phosphorus and Sulphur content in rice grain was higher than the rice straw. Potassium content in rice straw was about 6-8 times higher than rice grain. Organic manuring slightly increased total N, available P and S and exchangeable K in post harvest soil compared to initial soil. Increasing trend in cowdung and vermicompost content was observed in soil where organic manures were applied.

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

- I. Combined application of 100 kg N as the source of urea along with 20 kg N as the source of vermicompost performed the best in recording yield and yield contributing characters of NERICA 10
- II. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances;

CHAPTER VI

REFERENCES

- Abro, M.B. and Abbasi, Z.A. (2002). Effect of *Sesbania rostrata* (dhaincha) green manure on the yield of rice. *Journal of Applied Science* **2**(7): 768-769.
- AIS (Agricultural Information Service) (2011). *Krishi Dairy*. Agricultural Information Service. Dhaka, Bangladesh. 20-22.
- Alam, S.S., Moslehuddin, A.Z.M., Islam, M.R. and Kamal, A.M. (2006). Soil and foliar application of nitrogen for Boro rice (BRRI dhan 29). *Journal of Bangladesh Agricultural University* **8**(2): 199–202.
- Ali, S.M.H., Kabir, M.L. and Begum, M. (2001). Response of boro rice to organic and inorganic sources of nitrogen. *Bangladesh Journal of Train and Develop* **14**(1&2): 123-131.
- Atera, E.A., Onyango, J.C., Azuma, T., Asanuma, S. and Itoh, K. (2011). Field evaluation of selected NERICA rice cultivars in western Kenya. *African Journal of agricultural research* **6**(1): 60-66.
- Aulakh, M.S., Khera, T.S., Doran, J.W. and Bronson, K.F. (2001). Managing crop residues with green manure, urea, and tillage in a rice-wheat rotation. *Soil Science Society of America Journal* **65**: 820-827.
- Awan, K.H., Ranjha, A.M., Mehdi, S.M., Sarfraz, M. and Hassam, G. (2003). Response of rice line PB-95 to different NPK levels. *Online Journal of Biological Science* **3**: 157-166.
- Azad, B.S. and Leharia, S.K. (2002). Yield maximization of rice (*Oryza sativa*) through integrated nutrient management under irrigated conditions. *Journal of Environment and Ecology* **20**(30): 532-539.

- Azmi, N.Y., Sing, A.P., Sakal, R. and Ismail, M. (2004). Long term influence of intensive cropping and fertility levels on the build-up of sulphur and its influence on crop performance. *Journal of Indian Society of Soil Science* **52**(1): 85-88.
- Bahmania, M.A. and Ranjbar, G.A. (2007). Response of rice cultivars to rates of nitrogen and potassium application in field and pot conditions. *Pakistan Journal of Biological Science* **10**(9): 1430-7.
- Bahmaniar, M.A., Ranjbar, G.A. and Ahmadian, S.H. (2007). Effects of N and K applications on agronomic characteristics of two Iranian and landrace rice (*Oryza sativa* L.) cultivars. *Pakistan Journal of Biological Science* **10**(6): 880-6.
- Bahmanyar, M.A. and Mashaee, S.S. (2010). Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice (*Oryza sativa*). *African Journal of Biotechnology* **9**(18): 2648-2653.
- Balakrishnan, M., Ravisankar, N. and Swarnam, T.P. (2010). Influence of prickly sesban (*Sesbania cannabina*) intercropping in wet-seeded rice (*Oryza sativa*) on productivity, profitability and nitrogen balance under island ecosystem. *Indian Journal of Agricultural Science* **80**(1): 85-87.
- Barbarick (2008). *Nitrogen Sources and Transformations*. Colorado State University. U.S. Department of Agriculture.
- Batjes, N.H. (1996). Total C and N in soils of the world. *European Journal of Soil Science* **47**:151-163.
- BBS, (2011). *Monthly Statistical Bulletin of rice news on 8 December, 2011*. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government People's Republic of Bangladesh, Dhaka. 65.
- Bhuiyan, N.I., Shaha, A.L. and Panaullah, G.M. (1991). Effect of NPK fertilizer on the grain yield of transplanted rice and soil fertility. Long term study. *Bangladesh Journal of Soil Science* **22**(1&2): 41-50.

- Bhuvanewari, R. and Chandrasekharan, M.V. (2006). Influence of organic manures in conjunction with sulphur on yield and nutrient uptake by rice. *Journal of Plant Science* **19**(2): 543-545.
- Bhuvanewari, R., Chandrasekharan, M.V. and Ravichandran, M. (2007). Effect of organic sulphur and graded levels of sulphur on rice yield and sulphur use efficiency. *Journal of International Academia* **2**(2): 51-54.
- Black, C.A. (1965). *Methods of Soil Analysis Part I and II*. American Society of Agronomy. Incorporated Publication Madison, Wisconsin, USA.
- Bouyoucos, J.S. (1926). The hydrometer as a method for the mechanical analysis of soil. *Soil Science* **23**: 343-353.
- Bremner, J.M. and Mulvaney, C.S. (1982). Total Nitrogen in Methods of Soil Analysis. American Society of Agronomy. Inc. Madison, Wisconsin, USA: 595-622.
- Carreres, R., Sendra, J., Ballesterose, R. and Cuadra, J.G. (2000). Effect of pre-flood nitrogen rate and mid season nitrogen timing on flooded rice. *Journal of Agricultural Science* **134**(4): 379-390.
- Chandel, R.S., Singh, A.K. and Sudhakar, P.C. (2003). Effect of sulphur nutrition in rice (*Oryza sativa* L.) and mustard (*Brassica juncea* L.Czern and Coss.) grown in sequence. *Indian Journal of Plant Physiology* **8**(2): 155-159.
- Channabasavanna, A.S. and Biradar, D.P. (2003). Response of irrigated rice to the application of poultry manure and inorganic fertilizers N, P and K in Karnataka, India. *International Rice Research Newsletter* **26**(2): 64-65.
- Channabasavanna, A.S., Yelamadi, S.G. and Biradar, D.P. (2001). Response of rice (*Oryza sativa*) to sources of organic manures and levels of zinc phosphate in deep black soils. *Indian Journal of Agronomy* **46**(33): 458 – 461.
- Chaudhary, S.K., Singh, J.P. and Jhair, S. (2011). Effect of integrated nitrogen management on yield, quality and nutrient uptake of rice (*Oryza sativa*) under different dates of planting. *Indian Journal of Agronomy* **56**(3): 228-231.

- Chettri, M., Mondal, S.S. and Roy, B. (2002). Studies on the effect of sources of potassium and sulphur with or without farmyard manure on the yield components, grain yield and percent disease index in rice under intensive cropping system. *Journal of International Academia* **6**(1): 45-50.
- Chopra, N.K. and Chopra, N. (2004). Effect of row spacing and nitrogen level on growth, yield and seed quality of scented rice (*Oryza sativa*) under transplanted conditions. *Indian Journal of Agronomy* **45**(2): 304-308.
- Chu Van Hach and Nguyen Thi Hong Nam (2006). Response of some promising high yielding varieties to nitrogen fertilizer. *Journal of Omonrice* **14**: 78-91
- Chun-yan, W.U., Tang, X., Chen, Y., Yang Sheng, M. and Sheng-hai, Y.E. (2011). Effect of fertilization systems on yield and nutrients absorption in japonica rice variety. *Journal of Environment Science* **23**(1): 132-137.
- Cong, P., Sat, C. and Hardter, R. (2001). Response of selected crops to K fertilization on major soil types in South Vietnam. *Plant nutrition, food security and sustainability of agro-ecosystems through basic and applied research*. Institute of Plant Nutrition, Hanrover, Germany. pp. 820-821.
- Das, T. and Sinha, A.C. (2006). Effect of organic and inorganic sources of nutrients on growth and yield of rice (*Oryza sativa*) under terai region of West Bengal. *Journal of Interacademia* **10**(1): 16-19.
- Debiprasad, D., Hrusikesh, P. and Ramesh, C. (2010). Effect of organic and inorganic sources of N on yield attributes, grain yield and straw yield of rice (*Oryza sativa*). *Journal of Agronomy* **4**(2): 18-23.
- Dongarwar, U.R., Patankar, M.N. and Pawar, W.S. (2003). Response of rice to different fertility levels. *Journal of Soils Crops* **13**(1): 120-122.
- Dunn, D.J. and Stevens, G. (2008). Response of rice yields to phosphorus fertilizer rates and polymer coating. *Journal of Agricultural Science* **42**(3): 34-37.

- Elliott, E.T. (1986). Aggregate structure and carbon, nitrogen, and phosphorus in native and cultivated soils. *Soil Science Society of America Journal* **50**: 627-633.
- Esfehani, M., Sadrzade, S.M., Kavooosi, M. and Dabagh-Mohammad-Nasab, A. (2005). Study on the effect of different levels of nitrogen and potassium fertilizers on growth, grain yield, yield components of rice (*Oryza sativa*) cv. Khazar. *Iran Agronomy Journal* **7**(3): 226-241.
- FAO (2008). Production year book. Food and Agricultural Organization of the United Nations, Rome, Italy. 57.
- Gedam, V.B., Powar, M.S., Rudragouda, N.V., Mahskar, A. and Rametke, J.R. (2008). Residual effect of organic manures on growth, yield attributes and yield of rice in groundnut-rice cropping system. *Journal of Crops Science* **9**(2): 199-201.
- Gill, H.S. and Meelu, O.P. (1982). Studies on the substitution of inorganic fertilizers with organic manure and their effect on soil fertility in rice-wheat rotation. *Fertilizer Response* **3**: 303-314.
- Gupta, J.P., Surishta, D., Pardeep, W. and Devis, W.P. (2000). Influence of FYM and P levels on yield and its uptake on rice. *Indian Journal of Agricultural Science* **15**(1): 55-57.
- Hach, C.V. and Nam, N.T.H. (2006). Responses of some promising high yielding varieties to nitrogen fertilizer. *Journal of Omonrice* **14**: 78-91.
- Haque, M.A. (1999). Response of BRRI Dhan 29 to S, Zn and B supplied from manures and fertilizers. MS Thesis, Dept. of Soil Science (January-June Semester), 1999, BAU.
- Hong, X., Harmata, M. and Ghosh, S.K. (2004). [Tetrahedron Letters](#) **45**: 5233-5236.
- Hu, H., Wang, G.H. and Zhang, Q. (2004). Potassium uptake and use efficiency of rice under low-potassium stress field conditions. *Chinese Journal of Rice Science* **18**(6): 527-532.

- Indrani, P., Bora, K., Arundhati, B. and Jasbir, S. (2008). Integrated use of legume green manure and inorganic fertilizer on soil health, nutrient uptake and productivity of rice (*Oryza sativa*) in shifting cultivation of Assam. *Indian Journal of Agricultural Research* **42**(4): 260-265.
- IPCC 1996, Climate Change (1995). *The Science of Climate Change*. Cambridge University Press, Cambridge.
- Islam, M.R., Saha, P.K., Zaman, M.J. and Uddin, S.K. (2010). Phosphorus fertilization in inbred and hybrid rice. *Journal of Biological Science* **19**(2): 181-187.
- Jackson, M. L. (1962). *Soil Chemistry Analysis*. Prentice Hall Inc. Engle Wood Cliffe, N. J., USA: 55-56.
- Jacqueline, A., Prudente, A., Gilbert, C., Sigua, M., Manoch, K. and Alfredo, D. (2008). Improving yield and nutrient uptake potentials of Japonica and Indica rice varieties with nitrogen fertilization. *Journal of Agricultural Science* **4**(4): 427-434.
- Jadhav, A.D., Talashilkar, S.C. and Powar, A.G. (1997). Influence of conjunctive use of FYM, vermicompost and urea on growth and nutrient uptake in rice. *Journal of Agricultural Science* **32**(3): 249-250.
- Ji-ming, W., Qing, H., Tian, Y., Jin, H. and Chu, X. (2011). Effects of long-term green manure application on rice yield and soil nutrients in paddy soil. *Journal of Plant Nutrition and Fertilizer Science* **42**(12): 145-155.
- Ju-mei, L. (2008). Effects of chemical fertilizer and organic manure on rice yield and soil fertility. *American Journal Society of Soil Science* **42**(2): 543-551.
- Kabir, M.A., Sarkar, R. and Chowdhury, S. (2009). Effect of urea super granules, prilled urea and poultry manure on the yield of transplant Aman rice varieties. *Journal of Soil Science* **7**(2): 259-263.

- Kalaivanan, D. and Oma, K. (2007). Influence of enriched pressmud compost on soil chemical properties and yield of rice. *Research Journal of Microbiology* **3**(4): 354-361.
- Kalita, U., Das, J.R. and Suhrawardy, J. (2002). Effect of seed priming with potassium salt and potassium levels on growth and yield of direct seeded summer rice under rainfed upland condition. *Indian Journal of Hill Farming* **15**(1): 50-53.
- Kamara, A.Y., Ekeleme, F., Omoigui, L.O. and Chikoye, D. (2011). Influence of nitrogen fertilization on yield and yield components of rain-fed lowland NERICA® rice in the northern Guinea savanna of Nigeria. *African Journal of Agricultural Research* **6**(13): 3092-3097.
- Karim, Z., Miah, M. M. U. and Razia, S. (1994). Fertilizer in the national economy and sustainable environmental development. *Asia Pacific Journal Environment Development* **1**. 48-67.
- Karim, Z., Rahman, S.M., Idris, M. and Karim, A.J.M.S. (1988). *A Manual for the Determination of Soil Physical Parameters*. Soil and Irrigation Division, BARC, Dhaka. pp. 3-21.
- Kavitha, M.P., Balasubramanian, R., Babu, R. and Pand, V.K.P. (2008). Effect of nitrogen and potassium management on yield attributes, yield and quality parameters of hybrid rice. *Crop Research Hisar* **35**(3): 172-175.
- Kobayashi, Y., Abe, S. and Matumoto, K. (1989). Growth and yield of paddy rice under natural cultivation. *Rept. Tokoku Branch Crop Cci. Soc. Japan.* 32:12-13. Cited from *soils and fertilizer* (1991). **54**(12): 1932
- Krishnappa, M., Gowda, K.N., Shankarayan, V., Maharudrappa and Khan, M.M. (2006). Effect of graded levels and split application of potassium on its availability and yield of rice. *Journal of Potassium Research* **6**(4): 156-161.

- Kumar, T., Kumar, V., Singh, G., Singh, O.P. and Singh, R.G. (2008). Effect of pressmud and inorganic fertilizers on yield and nutrient uptake by rice and its residual effect on succeeding wheat and soil fertility in rain fed lowlands. *Journal of Agricultural Science* **3**(1): 220-222.
- Kumar, V. (2003). Integrated effect of chemical fertilizer and green manure forms of nitrogen and their availability under rice-wheat cropping system in calciorthents. *Journal of the Indian Society of Soil Science* **51**: 561-564.
- Kumar, V. and Singh, O.P. (2006). Productivity and Economics of rice-wheat cropping system as influenced by organic manures and fertilizer management under irrigated conditions. *Indian Journal of Agricultural Science* **2**(2): 629-632.
- Lal, R., Follette, R., Stewart, B.A. and Kimble, J.M. (2008). Soil carbon sequestration to mitigate climate change and advance food security. *Soil Science* **172**: 943-956.
- Li, Y.F., Luo, A.C., Wei, X.H. and Yao, X.G. (2007). Genotypic variation of rice in phosphorus acquisition from iron phosphate. contributions of root morphology and phosphorus uptake kinetics. *Russian Journal* **54**(2): 230-236.
- Mahavishnan, K., Reddy, A.S. and Rekha, K.B. (2004). Effects of organic sources of plant nutrients in conjunction with chemical fertilizers on growth, yield, quality of rice. *Journal of Crop Research* **5**(2-3): 159-161.
- Mandal, P.K., Anand, A. and Baig, M.J. (2000). Response of alfalfa genotypes to saline water irrigation. *Biological Planetarium* **43**(3): 455-457.
- Manivannan, R., Sriramachand, R.M.V. and Ravichandran, M. (2008). Influence of sulfur on the growth and yield of rice genotypes. *Journal of Crop Research* **9**(3): 518-520.
- Mann, K.K., Brar, B.S. and Dhillon, N.S. (2006). Influence of long-term use of farmyard manure and inorganic fertilizers on nutrient availability. *Indian Journal of Agricultural Science* **76**(8): 72-77.

- 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. *Indian Journal of Agricultural Science* **13**(1-2): 203-210.
- Mashkar, N.V. and Thorat, S.T. (2005). Effects of nitrogen levels on NPK uptake and grain of scented rice varieties under Konkan condition, Nagpur, India. *Journal of Soil Science* **15**(1): 206-209.
- Maskina, M.S., Singh, Y. and Singh, B. (1987). Effect of levels of nitrogen fertilizer on the yield and quality of rice. Cited from *Field Crop Abstract* **24**(6): 527-528.
- Mazumder, M.R., Bhuiya, M.S.U. and Hossain, S.M.A. (2005). Effect of N level and split application of *Sesbania rostrata* as green manure on the performance of transplanted aman rice cv. BRRI dhan 31. *Bangladesh Journal of Agricultural Science* **31**(2): 183-188.
- Mghase, J.J., Shiwachi, H., Nakasone, K. and Takahashi, H. (2010). Agronomic and socio-economic constraints to high yield of upland rice in Tanzania. *African Journal of Agricultural Research* **5**(2): 150-158.
- More, S.D. (2003). Effect of farm waste and organic manure on soil properties, nutrient availability and yield of rice-wheat sequence grown on sodic vertisol. *Journal of the Indian Society of Soil Science* **42**(12): 253-256.
- Morteza, A., Siavoshi, S., Shankar, K., Laxman, A., Laware, D., Shankar, L. and Laware, S.L. (2011). Effect of organic fertilizer on growth and yield components in rice (*Oryza sativa*). *Indian Journal of Agricultural Science* **3**(3): 32-33.
- Mostofa, A., Raju, R.A. and Reddy, K.A. (2009). Response of rice (*Oryza sativa*) to nitrogen, phosphorus and potassium fertilizer on Godavari alluvia's. *Indian Journal of Agronomy* **38**(4): 637-638.

- Moula, S.M. (2005). Comparative performance of rock phosphate and TSP on T. Aman rice in Old Brahmaputra Flood Plain and Old Himalayan Piedmont plain soils, MS Thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh.
- Muang斯里. M., Chanchareonsook, J. and Sarobol, E. (2008). Effect of rice straw and rice hull in combination with nitrogen, phosphorus and potassium fertilizer on yield of rice grown on phimal soil series. Proc. 46th Kasetsart University, Annual Conference, Kasetsart 29 January 1 February 2008.
- Naik, B.B. and Yakadri, M. (2007). Effect of integrated nutrient management on yield of hybrid rice (*Oryza sativa*). Journal of Crop Research **32**(3): 85-89.
- Naing, A., [Banterng](#), P., [Polthane](#), A. and Trelo, V. (2010). Effect of different fertilizers management strategies on growth and yield of upland black glutinous rice and soil properties. Journal of Plant Science **9**(12): 414-422.
- Nair, C.S. and Rajasree, B. (2004). Efficiency of phosphate concentrate (34/74) and super phosphate at two levels on yield characters of rice in the neutral to alkaline soils of Chittoor palaghat Kerala. Indian Journal of Agronomy **46**(3): 98-104.
- Natarajan, S., Ganapathy, M., Arivazhagan, K. and Manivannan, K. (2005). Effect of different levels of nitrogen and potassium on growth, nutrient uptake and yield of hybrid rice. Indian Journal of EcoBiology **17**(6): 593-595.
- Ogbodo, E.N. (2005). Response of rice (*Oryza sativa*) to organic and inorganic manures in an Ultisols. Journal of Agriculture, Forestry and Social Sciences **3**(1): 9-14.
- Oikeh, S.O., Nwilene, F., Diatta, S., Osiname, S., Touré, O. and Okeleye, K.A. (2008). Responses of upland NERICA rice to nitrogen and phosphorus in forest agroecosystem. Agronomy Journal **100**: 735-741.
- [Oikeh](#), S.O., [Touré](#), A., [Sidibé](#), B., [Niang](#), A., [Semon](#), M., [Sokei](#), Y., and [Mariko](#), M. (2009). Responses of upland NERICA rice varieties to nitrogen and plant density. Archives of Agronomy and Soil Science **55**(3): 301-314.

- Okonji, C.J., Okeleye, K.A., Aderibigbe, S.C., Oyekanmi, A.A., Sakariyawo, O.S. and Okelana, M.A.O. (2011). Effect of Cowpea Residue Incorporation and Nitrogen Application Rates on the Productivity of Upland Rice. *World Journal of Agricultural Sciences*, **7**(6): 710-717.
- Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. U.S. Department of Agricultural Circ. 929.
- Page, A. L., Miller, R. H. and Keeny, D. R. (1982). *Methods of Soil Analysis. Part II* (2nd ed.). American Society of Agronomy. Inc. Madison, Wisconsin, USA.
- Parvez, M.M., Harun-Ar-Rashid, M., Parvez, S.S. and Islam, M.T. (2003). Performance of Hybrid Rice in Bangladesh. A Comparative Study. *Japanese Journal of Tropical Agriculture* **47**(3): 215-221.
- Patel, K.P., Bhajan, S. and Chhibba, I.M. (2010). Crop yields and properties of a sodic soil as influenced by S-containing amendments under draining and non-draining conditions. *Journal of Arid Soil Research* **4**(3): 173-180.
- Patra, A.K., Chhonkar, P.K. and Khan, M.A. (2004). Effect of top dressing with green manure of (*Sesbania sesban*) on mineral nitrogen in soil and yields of hybrid rice. *Indian Journal of EcoBiology* **26**(12): 154-156.
- Paul, A.K., Rattan, R.K., Singh, A.K. and Datta, S.P. (2005). Influence of tillage, water regimes and integrated nutrient management on the macro-aggregate formation in cultivated soil under rice-wheat cropping system. *Journal of Agricultural Science Technology* **6**(1& 2): 78-84.
- Peng, J.G., Zhang, M.Q., Lin, Q., Yang, J. and Zhang, Q.F. (2002). Effect of sulphur on the main cereal and oilseed crops and cultivated soil available S status in Southeast Fujian. *Journal of Agricultural Science* **17**(4): 52-57.
- Rabindra, N., Mishra, M.S., Rajani, K. and Sahu-Sanjat, K. (2005). Effect of vermicomposted municipal solid wastes on growth, yield and heavy metal contents of rice (*Oryza sativa*). *Fresenius Environ. Bull.*, **14**: 584-590.

- Rahman, M.H., Islam, M.R., Jahiruddin, M. and Haque, M.Q. (2011). Economics of fertilizer use in the maize-mungbean/dhaincha-T. aman rice cropping pattern. *Journal of Bangladesh Agricultural University, Mymensingh* **9**(1): 37-42.
- Rajarathinam, P. and Balasubralnanian, P. (1999). Effect of plant population and nitrogen on yield attributes and yields of hybrid rice (*Oryza sativa*). *Indian Journal of Agronomy* **44**(4): 717-721.
- Rajni, Rani, Srivastava, O.P. and Rani, R. (2001). Effect of integration of organics with fertilizer N on rice and N uptake. *Journal of Soils and Fertilizers* **46**(9): 63-65.
- Raju, R.A. and Reddy, M.N. (2001). Response of hybrid and conventional rice to manure, sulphur and zinc application. *Journal of Soils and Fertilizers* **46**(11): 61-62.
- Ram, S., Chauhan, R.P.S., Singh, B.B. and Singh, V.P. (2000). Integrated use of organic and fertilizer nitrogen in rice (*Oryza sativa*) under partially reclaimed sodic soil. *Indian Journal of Agricultural Science* **70**(2): 114-116.
- Ravi, S., Ramesh, S. and Chandrasekaran, B. (2007). Influence of foliar application of phytohormones and nutrients on yield and nutrient uptake of transplanted rice in Annamalainagar, India. *International Journal of Plant Science* **2**(1): 69-71.
- Reddy, V.C., Ananda, M.G. and Murthy, K.N.K. (2006). Effect of different nutrients sources on growth and yield of paddy. *Journal of Environment and Ecology* **22**(4): 622-626.
- Saha, P.K., Ishaq, M., Saleque, M.A., Miah, A.M., Panaullah, G.M. and Bhuiya, 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. *Journal of Soil Science and Plant Analysis* **38**(5-6): 579-610.
- Saitoh, K., Kuroda, T. and Kumano, S. (2001). Effect of organic fertilization and pesticide application on growth and yield of rice for 10 years. *Japanese Journal of Crop Science* **70**(4): 530-540.

- Salahuddin, K.M., Chowhdury, S.H., Munira, S., Islam, M.M. and Parvin, S. (2009). Response of nitrogen and plant spacing of transplanted Aman rice. *Bangladesh Journal of Agricultural Research* **34**(2): 279-285.
- Salton, N.A., Wilson, C.E., Sabbe, W.E., Ntamatungiro, S., Frizzell, D. and Norman, R.J. (1999). Rice response to phosphorus and potassium fertilization at different soil test levels. Research Series, Arkansas Agricultural Experiment Station. No. **463**: 52-56.
- Sarfaraz, M., Mehdi, S.M., Sadiq, M. and Hassan, G. (2002). Effect of sulphur on yield and chemical composition of rice. *Sarhad Journal of Agriculture* **18**(4): 411-414.
- Sarkar, S. and Singh, S.R., (2002). Effect of K on soil fertility and yield sustainability under dry land farming. *Indian Journal of Agricultural Science* **67**(9): 431-433.
- Sarvanan, A., Velu, V. and Ramanath, K.M. (1987). Effect of combined application of bioorganic and chemical fertilizers on physical properties, nitrogen transformation and yield of rice in submerged soils. *Oryza*. 1-6.
- Sharma, S.N. and Prasad, R. (2003). Yield and P uptake by rice and wheat grown in a sequence as influenced by phosphate with or without crop residues and phosphate solubilizing bacteria. *Journal of Agricultural Science* **141**(3-4): 359-369.
- Shen, W., Zhang, G., Ma, L.M., Gu, W.G., Szmidt, R., Shen, W.Q. and Zhang, G.P. (2003). Uptake of nitrogen, phosphorus and potassium by maize and effects of nitrogen and potassium on plant yield and quality in paddy field soil. *Journal of Plant Nutrition* **26**(4): 457-458.
- Singh, A.P., Raha, P. and Yadav, P.K. (2005). Effect of sulphur and manganese fertilization on content and quality of rice bran oil. *Indian Journal of Agricultural Biochemistry* **18**(1): 19-23.
- Singh, C.S. and Singh, U.N. (2002). Effect of nitrogen and sulphur nutrition on growth and yield of rice (*Oryza sativa* L.) cultivars. *Journal of Crop Research* **3**(3): 645-646.

- Singh, M.K., Thakur, R., Verma, U.N., Upasani, R.R. and Pal, S.K. (2000). Effect of planting time and nitrogen on production potential of Basmati rice cultivars in Bihar Plateau. *Indian Journal of Agronomy* **45**(2): 300-303.
- Singh, R.N., Singh, S. and Kumar, B. (2005). Effect of integrated nutrient management practices in rice in farmer's fields. *Journal of Research, Birsa Agricultural University* **17**(2): 185-189.
- Singh, R.N., Singh, S., Prasad, S.S. and Singh, V.K. (2010). Effect of integrated nutrient management on soil fertility, nutrient uptake and yield of rice-pea cropping system on an upland acid soil of Jharkhand. *Journal of the Indian Society of Soil Science* **59**(2): 158-163.
- Singh, R.P., Yadav, P.K., Singh, R.K., Singh, S.N., Bisen, M.K. and Singh, J. (2006). Effect of chemical fertilizer, FYM and biofertilizer on performance of rice and soil properties. *Journal of Crop Research* **32**(2): 283-285.
- Singh, S. and Prasad, K. (2001). Effects of fertilizers, FYM, and row spacing on transplanted rice. *Journal of Crop Research (Hisar)* **22**(2): 295-296.
- Singh, S.P., Devil, B.S. and Subbiah, S.V. (1998). Effect of N levels and lime application on grain of hybrid rice. *International Journal of Rice Research Institute* **23**(1): 25-26.
- Solaiman, A.R.M., Jahiruddin, M. Karim, M. and Nasim, A.S. (2011). Effect of urea-nitrogen, cowdung, poultry manure and urban wastes on yield and yield components of boro rice. *Journal of Agriculture, Environment and Biotechnology* **4**(1): 9-13.
- Spaccini, R., Mbagwu, J.S.C., Igwe, C.A., Conte, P. and Piccolo, A. (2004). Carbohydrates and aggregation in lowland soils of Nigeria as influenced by organic inputs. *Soil and Tillage Res.* **75**(2): 161-172.
- Sreelatha, T., Raju, A.S. and Raju, A.P. (2006). Effect of different doses of farmyard manure and poultry manure and their interaction with fertilizer nitrogen on yield and nutrient uptake in mesta-rice cropping system. *Journal of Crop Research* **34**: 41-47.

- Surekha, K., Pavan, C.R.K., Padma, K.A.P. and Sta Cruz, P.C. (2006). Effect of straw on yield components of rice (*Oryza sativa* L.) under rice-rice cropping systems. *Journal of Agronomic Crop Science* **192**: 92-101.
- Tang, X., Shi, Y.M. and Hao, X. (2011). Phosphorus efficiency in a long term wheat–rice cropping system in China. [*Journal of Agricultural Science*](#) **149**(3): 297-304.
- Uddin, M.K., Islam, M.R., Rahman, M.M. and Alam, S.M.K. (2009). Effects of sulphur, zinc and boron supplied from chemical fertilizers and poultry manure to wetland rice. *Journal of Biological Science* **2**(3): 55-57.
- Umanah, E.E., Ekpe, E.O., Ndon, B.A., Etim, M.E. and Agbogu, M.S. (2003). Effects of poultry manure on growth characteristics, yield and yield components of upland rice in South Eastern Nigeria. *Journal of Sustainable Agricultural and the Environment* **5**(1): 105-110.
- Usman, M., Ullah, E., Warrick, E.A., Earooq, M.A. and Liaqat, A. (2003). Effect of organic manures on growth and yield of rice variety "Basmati 2000" *International Journal of Agriculture and Biology* **5**: 481-483.
- Vaiyapuri, V. and Chandrasekharan, M.V. (2001). Integrated use of green manure and sulphur on nutrient uptake and rice yield. *Journal of EcoBiology* **13**(3): 223-227.
- Vanaja, M. and Raju, A.S. (2002). Integrated nutrient management performance in rice crop. *Journal of Annals of Agricultural Research* **23**(1): 51-56.
- Vennila, C. (2007). Integrated nitrogen management for wet seeded rice + dhaincha dual cropping system. *Journal of Soils and Crops* **17**(1): 14-17.
- Walkley, A. and Black, I.A. (1934). An examination of degtiareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

- Wan, T.Y., Shao, M., Jiang, H. and Zhou, Q.M. (2010). Effect of fertilizer application on rice yield, potassium uptake in plants, and potassium balance in double rice cropping system. *Journal of Environmental Science* **84**(3): 203-213.
- Wang, C.H. (2004). Response of rice yield to deep placement of fertilizer and nitrogen top-dressing during panicle initiation stage and its diagnosis of fertilizer application. *Taiwanese Journal of Agricultural Chemistry and Food Science* **42**(5): 383-395.
- Wang, W., Jian, L.U., Qing, Y., Xiao, K. and Hui, L. (2011). Effects of N, P, K fertilizer application on grain yield, quality, nutrient uptake and utilization of Rice. *Chinese Journal of Rice Science* **25**(6): 645-653.
- Yadav, S.K., Panwar, N.R. and Ramana, S. (2010). Effect of organic nitrogen on yield and nutrient composition of rice (*Oryza sativa* L.). *Indian Journal of Plant Physiology* **15**(1): 77-79.
- Yaduvanshi, N.P.S. and Sharma, D.R. (2005). Use of wheat residue and manures to enhance nutrient availability and rice-wheat yields in sodic soil under sodic water irrigation. *Journal of the Indian Society of Soil Science* **55**(3): 330-334.
- Yang, M.J., Lin, Q., Yang, J., Wei, F. and Zhang, M.Q. (2001). Study on the effects of sulphur fertilizer and nitrogen-sulphur balancing application of fertilizers to first cropping rice. *Chinese Journal of Rice Science* **1**: 2-3.
- Zaman, S., Hashem, M.A., Mian, M.H., Mallik, S.A. and Shamsuddoha, A.T.M. (2000). Effect of organic and inorganic sources of nitrogen, and potassium on physical and chemical properties of soil. *Bangladesh Journal of Agricultural Science* **27**(1): 71-76.
- Zhang, Y.L., Shen, Q.R. and Cao, C.Y. (1998). Effects of organic manure on soil organic phosphorus functions and their bioavailability. *Journal of Nanjing Agricultural University* **21**(3): 59-63.

APPENDICES

Appendix I. Analysis of variance of the data on yield contributing characters of NERICA 10

Sources of variation	df	Plant height (cm)	Panicle length (cm)	Effective tillers hill ⁻¹ (no.)	Filled Grain/Panicle (no.)	Un-filled Grain/Panicle (no.)	1000-seed weight (g)	Grain weight (t/ha)	Straw Weight (t/ha)
Replication	2	1.708	0.564	0.004	15.364	13.091	1.313	0.346	0.027
Factor A	10	12.137 **	0.892 *	5.359 **	48.764 **	20.564 **	15.873 **	1.771 **	2.261 **
Error	20	14.398	0.373	0.098	6.564	4.491	0.087	0.107	0.076

Appendix II. Analysis of variance of the data on N,P,K and S content(%) of NERICA 10

Sources of variation	df	Grain				Straw			
		N	P	K	S	N	P	K	S
Replication	2	0.001	0.002	0.001	0.018	0.001	0.001	0.001	0.001
Factor A	10	0.005 *	0.002 **	0.003 **	0.0017 **	0.011 *	0.001 NS	0.011 *	0.001 NS
Error	20	0.002	0.001	0.001	0.021	0.006	0.001	0.004	0.001

** = Significant at 1% level of probability, * = Significant at 5% level of probability,
 NS = Non Significant.

Appendix III. Analysis of variance of the data on N,P,K and S uptake (kg ha⁻¹) of
 NERICA 10

Sources of variation	df	Grain				Straw			
		N	P	K	S	N	P	K	S
Replication	2	23.165	8.434	1.063	49.910	0.042	0.007	1.603	0.043
Factor A	10	170.384 **	9.567 **	8.487 **	2.513 **	105.614 **	3.543 **	518.911 **	3.573 **
Error	20	8.834	0.267	0.991	64.489	14.712	0.529	21.070	0.685

Appendix IV. Analysis of variance of the data on N,P,K and S content of NERICA
 10 in soil.

Sources of variation	df	Grain			
		N (%)	P (ppm)	K (meq./100g soil)	S (ppm)
Replication	2	0.001	1.120	0.001	0.001
Factor A	10	0.001 NS	5.181 **	0.001 **	56.055 **
Error	20	0.001	0.414	0.001	0.070

** = Significant at 1% level of probability, * = Significant at 5% level of probability,
 NS = Non Significant.

