EFFECT OF INTEGRATED USE OF ORGANIC AND INORGANIC FERTILIZERS ON THE GROWTH AND YIELD OF BRRI dhan29

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CERTIFICATE

This is to certify that the thesis entitled " ***EFFECT OF INTEGRATED USE OF ORGANIC AND INORGANIC FERTILIZERS ON THE GROWTH AND YIELD OF BRRI dhan29"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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* ***ASHIK JAMIL MAHMUD,*** *Registration. No.* ***07-02481*** *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.

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Dhaka, Bangladesh

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ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during December 2013 to June 2014 to study the effect of 4 levels of vermicompost *viz.*, 0 t ha^{-1} (V_0), 1 t ha^{-1} (V_1), 2 t ha^{-1} (V_2), 4 t ha^{-1} (V_3) and 4 levels of chemical fertilizers *viz.*, F_0 = (0-0-0-0 kg ha^{-1} N, P, K, S, respectively), F_1= low level (50-8-33-6 kg ha^{-1} N, P, K, S, respectively), F_2 = medium level (100-16-66-12 kg ha^{-1} N, P, K, S, respectively), F_3 = high level (150-24-99-18 kg ha^{-1} N, P, K, S, respectively) on the growth, yield and nutrient concentration in grain and straw of boro rice (BRRI dhan29). Different levels of vermicompost and NPKS fertilizers showed significant effect on growth, yield and yield contributing characters of BRRI dhan29. Results showed that application of medium level of chemical fertilizers with 4 t ha^{-1} vermicompost gave the maximum yield. It was observed that over dose of NPKS fertilizers from chemical source decreased rice yield. Results also revealed that the highest plant height, effective tillers $hill^{-1}$, flag leaf length, panicle length, filled grains $panicle^{-1}$, 1000-grain weight, grain yield, straw yield and biological yield were obtained from the combination of 4 t ha^{-1} vermicompost with 100 kg ha^{-1} N, 16 kg ha^{-1} P, 66 kg ha^{-1} K, 12 kg ha^{-1} S. The highest dose of vermicompost and chemical fertilizer increased the concentration of P, K, and S by rice grain and straw significantly at the harvesting stage. Application of chemical fertilizer and vermicompost alone or combined failed to increase the total N content of post-harvest soil. Vermicompost and chemical fertilizers alone or combined increased the organic matter, P, K and S status of post harvest soil significantly.

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LIST OF ACCRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
CEC	Cation Exchange Capacity
cm	Centi-meter
cv.	Cultivar(s)
CV	Coefficient of Variance
et al.	and others
e. g.	example
etc.	Etcetera
FAO	Food and Agricultural Organization
FYM	Farm Yard Manure
g	gram
GM	Green Manure
H_3BO_3	Boric Acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
$hill^{-1}$	Per hill
i.e	that is
J.	Journal
kg	kilogram
kg ha^{-1}	kilograms per hectare
LSD	Least Significant Difference
m	Meter
ml	Milliliter
PM	Poultry Manure
RDF	Recommended Doses of Fertilizer
Res.	Research
RCBD	Randomized complete block design
Rep.	Replication
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
var.	Variety
viz.	namely
%	Percent
@	At the rate

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is an important cereal crop of the gramineae family and a major staple food that is widely consumed all over the world irrespective of race, religion and political association (Ohajianya and Onyenweaku, 2002). The crop is very unique among the World's major food crops by virtue of the extent of its uses as livestock feeds, raw material in many breweries and pharmaceutical industries and currently as a source of bio-fuel (Hirst, 2006 and Encyclopedia botanical, 2009). The adoption of modern farming practices and integrated nutrient management are essential to produce crops in line with the observed global standards of quantity and quality. In most tropical farming communities, the use of inorganic fertilizers to boost yield of rice cannot be under-estimated as they have been found to increase crop performance as well as the chemical properties of soils (Ojeniyi, 2000). Owing to high grain yield, wetland rice removes a substantial amount of major and minor nutrients from the soil, and deficiency of either nutrient reduces. But with the present day high yielding cultivars, which have higher nutrient requirements, the use of inorganic fertilizers has increased considerably leading to decline in the use of organic materials (Hossain and Singh, 2000). To get more food, farmers are using chemical fertilizers and pesticides, in increasing amount which are making ecological backlashes (Yawalker *et al.*, 1981). Extensive and inappropriate use of chemical fertilizers is degrading our soil to an alarming level (Satyanarayana *et al.,* 2002; Mahajan *et al.,* 2008) which could cause nutrient imbalance and soil acidity (Meena *et al.*, 2003, Doran *et al,* 2008, Mukhtar *et al.*, 2011) which leads to deterioration in soil chemical and physical properties, biological activity and generally in soil health (Mahajan *et al.*, 2008). Nutrients supplied exclusively through chemical sources, though enhance yield initially, lead to unsustainable productivity over the years (Satyanarayana *et al.,* 2002; Mahajan *et al.*, 2008).

Organic matter in soil is an imperative indicator of soil fertility (Rahman and Parkinson, 2007) which can improve soil structure, nutrient exchange and maintain soil physical conditions (Ayoub, 1999; Becker *et al.,* 1995). Organic fertilizers not only act as the source of nutrients, but also provide micronutrients and modify soil-physical behaviour as well as increase the efficiency of applied *nutrients* (Pandey *et al.,* 2007). Organic matter undergoes mineralization with the release of substantial quantities of N, P, K & S and smaller amounts of micronutrients. Easily decomposable part of soil organic matter undergoes quick mineralization and becomes a part of soil humus, a small portion of which may remain in soil for long time. In Bangladesh, most of the cultivated soils have less than 1.0% organic matter while a good agriculture should contain at least 2% organic matter. Moreover, this important component of soil is declining with time due to rapid decomposition enhanced by high temperature and high rainfall with little or no addition of organic manure. Evidences from different AEZs of the country have shown decrease in the content of organic matter by the range of 15 to 30% over the 20 years (Miah, 1994). Addition of organic matter in soil is a pre-requisite for efficient cycling of nutrients. Organic manure sources however, are associated with problems relating to inadequate availability, low quality depending on the type, transportation and handling problems, high C: N ratio, heavy metal pollution and slow nutrient release (Ayeni *et al.,* 2010).

Vermicompost has been considered as a soil additive to reduce the use of mineral fertilizers because it provides required nutrient amounts, increases cation exchange capacity and improves water holding capacity (Tejada and Gonzaler, 2009). Vermicompost not only increases yield of rice but can also substitute chemical fertilizer to some extent (Jeyabala and Kuppuswamy, 2001; Barik *et al.,* 2006; Sharma *et al.,* 2008; Guera, 2010).

The single use of either organic or inorganic fertilizers in recent years have not really met the expected impact in boosting crop yield to cope with the geometric demand hence, integrated nutrient supply have been advocated by the Food and Agricultural Organization of the United Nation (Olowokere, 2004). Despite massive efforts of research workers the yield has not been improved according to the genetic potential of the varieties (Yaqoob *et al.,* 2012). Average yield of rice varieties is much lower than production potential which might be due to imbalanced supply of nutrients.

Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity (Satyanarayana *et al.,* 2002; Jobe, 2003). Furthermore, the price of inorganic fertilizers is increasing and becoming unaffordable for resource-poor smallholder farmers. The best remedy for soil fertility management is, therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil (Jobe, 2003). The combined application of inorganic and organic fertilizers, usually termed integrated nutrient management, is widely recognized as a way of increasing yield and or improving productivity of the soil sustainably (Mahajan *et al.,* 2008). Several researchers (Singh and Singh, 2000; Mahajan *et al.,* 2008) have demonstrated the beneficial effect of integrated nutrient management in mitigating the deficiency of many secondary and micronutrients. It is widely recognized that neither use of organic manures alone nor chemical fertilizers can achieve the sustainability of the yield under the modern intensive farming. Contrary to detrimental effects of inorganic fertilizers, organic manures are available indigenously which improve soil health resulting in enhanced crop yield. However, the use of organic manures alone might not meet the plant requirement due to presence of relatively low content of nutrients. Application of organic manure with chemical fertilizer accelerates the microbial activity (Rani and Srivastava, 1997), increases nutrient use efficiency (Narwal and Chaudhary, 2006) and enhances the availability of the native nutrients to the plants resulting higher nutrient uptake (Bhandari *et al.*, 1992). Therefore, in order to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in combination with inorganic fertilizers to obtain optimum yields (Ramalakshmi *et al.*, 2012).

Keeping these facts in mind, the present investigation was undertaken to study the effect of combined application of vermicompost and chemical fertilizers on yield and yield attributes of boro rice and its impact upon soil nutrient status and uptake of nutrients in grain. Information is limited regarding combined application of organic and inorganic fertilizers with respect to the soil and crops of Bangladesh under the existing agro-climate conditions which needed to be suited.

Considering the above facts the present experiment has been undertaken with rice as the test crop for the following objectives:

1. To study the individual and combined effect of vermicompost and NPKS fertilizers on the growth and yield of rice; and
2. To know the optimum dose of vermicompost and NPKS fertilizers on the growth and yield of rice.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Soil organic manures and inorganic fertilizers are the essential factors for sustainable soil fertility and crop productivity because organic matter is the store house of plant nutrients. Sole and combined use of cow dung, poultry manure, compost, and inorganic fertilizer acts as a source of essential plant nutrients. Experimental evidences in the use of cow dung, poultry manure, compost, vermicompost and nitrogen, phosphorus, potassium and sulphur showed an intimate effect on the yield and yield attributes of rice. A better understanding of the effects of organic and inorganic fertilizers on BRRI dhan29 in our soils will facilitate the development of suitable soil management practices for better and sustainable production of the crops. Brief reviews of available literature pertinent to the present study have been reviewed in this chapter.

2.1 Effect of manure on the growth and yield of rice

Dada *et al.* (2014) reported that cattle dung + maize stover enhanced growth, nutrient use efficiency, dry matter and grain yield of upland rice cultivars. They also revealed that residual effect of compost on growth, yield and nutrient uptake efficiency of upland rice on nutrient deficient soil was marginal.

Sujatha *et al.* (2014) indicated that maximum yield of rice was recorded with recommended dose of fertilizers which was on a par with 50% RDN as basal +50% at 10 days before PI stage through poultry manure. Among different organic manure treatments, application of 100% RDN through FYM recorded highest amount of NPK in soil after harvest, followed by application of 50% RDN as basal +50% at 10 days before PI stage through FYM which were however, on a par with each other. The lowest amount of NPK in soil after harvest was recorded with the application of recommended dose of chemical fertilizers followed by 100% RDN through poultry manure.

Pontillas *et al.* (2009) studied on the effect of vermicompost on the growth and yield of rice. They found that the application of vermicompost alone and the combination of inorganic fertilizer and vermicompost resulted to no significant differences in the height in comparison with inorganic fertilizer at 60 DAT. It was at harvest that rice applied with inorganic produced a significantly tallest plants among the treatments. This signifies a favorable effect on the growth and yield in rice production when vermicompost was supplemented with inorganic fertilizer and further implies that it can be a substitute to pure inorganic fertilizer application. Tejada and Gonzales (2008) on the application of vermicompost on rice crop showed a positive effects on biological and rice quality and yield performance.

Neither FYM nor chemical fertilizers alone could be sufficient to increase yield sustainability under cropping system where nutrient turnover in soil plant system has been much higher (Satyanarayana*et al.*, 2002).However, in an integrated nutrient managment, FYM can maintain plant nutrients in the available forms for longer periods due to improved soil organic matter (SOM) and soil physico-chemical and biological characteristics (Singh and Singh, 2000; Aziz *et al.*, 2010).Chemical fertilizers, on the other hand, offer nutrients which are readily soluble in soil solution and thereby make nutrients instantly available to plants (Aziz *et al.*, 2010). FYM is also reported to be a good source of nutrients such as phosphorus, potassium, and silica (Yoshida 1981; Mahajan *et al.*, 2008) and also it enhances availability of secondary and micronutrients (Aziz *et al.*, 2010; Bodruzzaman *et al.*, 2010).

Baibourdi *et al.* (2007) reported that organic fertilizers such as municipal solid waste compost are quite rich in plant nutrients. Municipal compost was applied at three levels (5, 10 & 15 t ha^{-1}) in rice filed. The highest yield was obtained at the rate of 15t ha^{-1}.

Banerjee *et al.* (2006) revealed that maximum production (9.26 t/ha/year) was recorded when the crop received 50% recommended doses of nutrients through fertilizer along with 50% doses of nutrient through green leaf manuring during kharif season and 100% recommended doses of nutrients through fertilizer during boro season. Use of green leaf to substitute half of the recommended NPK enhanced productivity by 0.6 to 1.1 % over sole chemical fertilization at the recommended level: Crop residue and FYM slightly decreased crop productivity as composed to sole chemical fertilization.

Miah *et al.* (2006) stated that an application of poultry manure with soil test basis (STB), IPNS and AEZ based fertilizer gave higher grain yield compared to other organic materials. McAndrews *et al.* (2006) conducted an experiment to investigate the residual effect of fresh or composted hoop house swine manure on the growth and yield of soybean. During both years, soybean plants from manure-amended plots were significantly taller and had a thicker stem diameter than plants from the other plots. The manure-treated plots produced 39% greater soybean leaf area than the control in 2001 and 11% greater leaf area than the urea-amended plots in 2002. There was a 21 to 34% greater K concentration in soybean plants grown in the manure-amended sites than in the other plots. Soybean grain yield was 0.2 to 0.5 Mg ha-1 greater in the manure-treated plots than the control or urea-fertilizer plots.

Chideshwari and krisnawamy (2005) conducted a pot experiment with rice cv. ADT 36, to study the effect of Zn enriched organic manures on yield.Transformation of Zn and their availability under submerged condition. Five Zn levels (0.0, 1.25, 2.5, 3.75 and 5.0 mg kg^{-1}) were enriched with 4 sources of organic manures at 1.0 t ha^{-1} (Farm Yard Manure FYM), composted their pith (CCP), FYM+ green leaf manure (without Zn enrichment) at 12 t ha^{-1}. The application of Zn enriched organic manures at 1.0 mg ha^{-1} was sufficient to get maximum yield compared the recommended dose of organic manures. The enrichment of Zn at 1.25 mg kg^{-1} with organic manures increased the grain yield of rice by 26% over no Zn application. Soil Zn fractions increased with increasing levels of enrichments. The complex organically bound and water soluble plus exchangeable fractions significantly affected the grain and dry matter yields, DTPA- Zn, Zn content and uptake at all stages of growth (maximum tillering, panicle initiation and harvest).

Reddy *et al.* (2005) carried out a field experiment on black clay soils in Gangavati, Karnakata, India, to evaluate the performance of poultry manure (PM) as a substitute for NPK in irrigated rice (cv. IR 64). The application of PM at 5 t ha^{-1} recorded a significantly higher grain yield (5.25 t ha^{-1}) than the control and FYM application at 7.5 t ha^{-1}, significantly improved the soil P and K status, and increased the N content of the soil. Poultry manure at 5 t/ha resulted in higher gross returns (30592 Rupees/ha) over other levels of PM and FYM. However, net returns and benefit cost rations were comparable between 5 and 2 t PM/ha, and between 100 and 75% NPK. The application of 2 t PM/ha and 75% NPK was found economical.

Bhattacharyya *et al.* (2005) reported the suitability of municipal solid waste compost (MSWC) application to submerged rice paddies in the perspective of metal pollution hazards associated with such materials. Soil microbial biomass-C (MBC), MBC as percentage of organic-C, urease and acid phosphatase activities were higher in DCM than MSWC treated soils, due to higher amount of biogenic organic materials like water soluble organic carbon, carbohydrate and mineralizable nitrogen in the former. The studied parameters were higher when urea was integrated with DCM or MSWC compared to their single applications.

Plants cultivated with selected compost presented a superior grain, being of 52.5% in stem diameter, 71.1 and 81.2% root and stem biomasses respectively. Chlorophy II content alterations were observed in plants from treatments using 30 ton compost ha^{-1} does onwards (Lima *et al.,* 2004).

Aga *et al.* (2004) assessed the effect of compost on the growth and yield of rice. Plant growth characters such as plant height were highest with application of 15 t compost/ha. Grain yield increased significantly with the graded levels of compost application @ 10 t/ha but the response decreased with the increase of compost from 10 to 15 t/ha. Saleque *et al.* (2004) stated that Poultry manure may be a good source of organic matter and nutrients for rice production.

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

Bhadoria *et al.* (2003) carried out an experiment to evaluate the relative efficacy of organic fertilizer, processed city waste (PCW), vermicompost (VC) and oil cake pellets (OCP). They showed that use of organic fertilizers improved tolerance of rice plants to attack by pathogens and pests. They also reported that grain yield increased due to use of organic fertilizer.

Arancon *et al.* (2003) suggested that the presence of plant growth influencing substances, such as plant growth hormones and humic acids in vermicompost, is also a possible factor contributing to increased yield.

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

Vijaayarama and Balasubramian (2002) reported that 28 days old rice seedlings were treated with different organic amendments (Farm Yard Manure, @ 50 kg N ha^{-1},neem cake at 50 kg N ha^{-1}+ urea @ 50 kg N ha^{-1}, press mud cake @ 50 kg N ha^{-1}+ urea at 50 kg N ha^{-1} and urea @ 100 kg N ha^{-1}) in a field experiment conducted in Rudrur, India during seasons of 1996 and 1997 to develop a suitable integrated nutrient supply system to reduce blast (*Pyriculariaoryzae*) incidence in the crop. Substitution of nitrogen through FYM has significant effect on reducing rice blast disease and increasing grain yield. Statistical analysis of data that supply of 50% the required nitrogen through FYM and remaining 50% through urea reduced the blast disease severity to a maximum extent and produced maximum yield.

Kumara and Kumari (2002) from an experiment stated that vermicompost is a potential source of organic manure due to the presence of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms like N fixing, P solubilizing and cellulose decomposing organisms. Mendoza (2002) found that the organic inputs were productive to increase yield in rice production.

The applied organic fertilizer increased rice yield, improve crop growth. They also recommended it for sustenance of soil fertility (Zahid *et al.,* 2001). Increase in grain yield due to application of organic fertilizers was observed by various workers (Ram *et al.,* 2000; Singh *et al.,* 2001 and Tiwari, 2001). Incorporation of organics increased the straw yield of rice (Ram *et al.,* 2000 and Tiwari, 2001).

Vermicompost produced higher yield of tomato than the chemical fertilizer treated and control plots. Same margin of production was obtained in snake gourd, bitter gourd and lady's finger. All the plots of lady's finger at once time were completely damaged due to severe virus attack. It was observed that crops grown under chemical fertilizer became yellowish rapidly while crops grown under vermicompost remained green. Germination of different seeds in the vermicomposted plots werehigher than the control and chemical fertilizer treated pots (Zahid, 2001).

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

Vermicompost contains 2.29 folds more organic carbon, 1.76 times total nitrogen, 3.02 folds phosphorus and 1.60 times potassium than normal compost. Earthworms decrease the C: N ratio from 14.21 to 10.11 and an average 56.03% of organic waste can be converted into vermicompost by the activities of earthworms in short time (Sohrab and Sarwar, 2001).

Dey and Jain (2000) observed the residual effect of GM and their enriched counterparts in terms of yield. N uptake by wheat and efficiencies of wheat was higher than that of urea treatment during preceding rice season. Quadratic models can effectively explain in the variation in yield and N uptake of rice with N application up to 100 kg N ha^{-1}. Significant and positive correlation exists between soil organic N on rice yield and N uptake of wheat. Linear model constituted with soil organic N with rice yield and N uptake and yield of residual wheat can significantly describe the variation.

Iwaishai (2000) reported that organic fertilizer increased kernel enlargement after the panicle formation stage, increased ear number and panicle length. Katyal and Gangwar (2000) found that the application of 25-50% of fertilizers in organic form gave the best yield stability. Ram *et al.* (2000) reported that the use of 30 or 60 kg N/ha from organic sources in a total application of 120 kg N/ha increased grain and straw yields, N uptake and recovery, grain nutritive value, decreased soil P and increased soil fertility and economic returns.

Rao et al. (2000) from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, revealed that application of 3 t vermicompost ha-1 to chickpea improved dry matter accumulation, grain yield and grain protein content in chickpea, soil N and P and bacteria count, dry fodder yield succeeding maize, total N and P uptake by cropping system over no compost. Dwivedi and Thakur (2000) observed that the highest grain yields of 4.77 and 4.84 t/ha with green manure (*Sesbania cannabina*) treated plots whereas fertilizer treated plots (100; 60; 40 kg NPK/ha) gave 4.32 and 4.44 t/ha, respectively. The results revealed that green manure and biogas slurry saved 50 and 25% NPK fertilizers, respectively.

Vasanthi and Kumaraswamy (1999) from an experiment with and NPK fertilizers showed that the grain yields of rice were significantly higher in the treatments that received vermicompost from any of the 5 to 10 t ha^{-1}, organic materials (sugarcane trash, ipomea, banana peduncle etc.) with N, P and k at recommended levels than in the treatment that received N, P and K alone. Organic carbon content and fertility status as reflected by the available status of N, P and K, micronutrients and CEC were higher and bulk density were lower in the treatments that received vermicompost plus N,P and K than in the treatments with N, P and K alone. It was found that vermicompost at 5 t ha-1 would be sufficient for rice crop when applied with recommended levels of N, P and K.

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

Dash *et al.* (2011) reported that application of recommended doses of fertilizer brought about maximum improvement in the different growth attributes such as total tillers, dry matter production and LAI in comparison to other sources of organic N carriers. These attributes were also observed to increase significantly over control due to various organic N sources. Application of N through chemical fertilizer brought about significant improvement in grain and straw yields of rice crop and established superiority over rest of the treatments.

Manivannan and Sriramachandrasekharan (2009) reported that highest yield obtained with recommended dose of chemical fertilizer was due to better growth and yield attributes recorded which in turn, resulted in increase of rice yields compared to added levels of N in organic form. Islam *et al.* (2008) conducted an experiment in 2001-2002, 2002-2003 and 2003-2004 to determine the response and the optimum rate of nutrients (NPK) for Chili- Fallow-T. *Aman* cropping pattern. They found that grain yield influenced significantly due to application of different rates of nutrients and 60-19-36 kg/ha NPK maximized the yield of T. *Aman* rice varieties in respect of yield and economics.

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

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of NPK increase Plant height. High levels of N fertilization can interfere with Mg uptake by crops (Havlin *et al.,* 2006) resulting in nutrient imbalance and reduced crop yield. Saha *et al.* (2004) conducted an experiment in 2002-2003 to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one check plot. Results show that the application of different packages estimated by different fertilizer models significantly influence panicle length, panicle numbers, spikelet number per panicle, total grains panicle^{-1}, number of filled grain and unfilled grain per panicle. The combination of NPK that gives the highest result was 120-13-70-20 kg/ha NPKS.

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

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

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

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

Haq *et al.* (2002) reported that the number of panicles increased with increase in the nitrogen rates and that number of panicles per plant increased with increase in NPK rates. Haq *et al.* (2002b) conducted an experiment with twelve treatments combination of N, P, K, S, Zn and Diazinon. He found all the treatments significantly increase the grain and straw yield of BRRI dhan30 rice over control. 90 kg N + 50 kg P_2O_5 + 40 kg K_2O + 10 kg S + 4 kg Zn ha^{-1} + diazinon gave the highest grain and straw yield.

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

Islam and Bhuiya (1997) reported that the effect of nitrogen and phosphorus on the growth, yield and nutrient uptake of deep water rice. They observed that nitrogen and phosphorus fertilization significantly increased the number of fertile tiller/m2 and also that of grains/panicle which in turn resulted in significant increase grain yield. The application of 60kg N/ha alone gave 22% yield benefit over control.

Senanayake *et al.* (1996) concluded that 10 kg ha^{-1} of N fertilizer had the positive effect on number of spikelet number when applied at growth stage but was too low to sustain the survival of the differentiated spikelets. Applications after panicle initiation did not lead to an increased survival of spikelets. Foliar N application at GS increased spikelet survival. Carreres *et al.* (1996) observed that grain yield increased with increasing amount of N fertilizer upto 70 kg N ha^{-1}.

Effective tillers per m^2 was increase upto 60 kg N/ha in both the year of 1993 and 1994 through the application of 120 kgN/ha (Chander and Pandey, 1996). Datta *et al.* (1995) reported increased number of tillers per hill due to application of sludge and industrial wastes.

The long-term research of BRRI revealed that the application of cowdung 5 t/ha/yr improved rice productivity as well as prevented the soil resources from degradation (Bhuiyan, 1994).

A field experiment was conducted in a typical lowland situation in farmer's field during the wet season of 1986. The results showed that the addition of N increased the number of ear-bearing tillers and number of grains/panicle. They also found that addition N increased grain yield significantly (Ghosh *et al.,* 1991). Thakur (1991) reported that the yield attributes like panicles/m^2 and panicle weight increased with increasing levels of N.

Wells et al. (1990) conducted a field experiment and found that the rice yield increased from 3236 kg ha^{-1} without N to 7710 kg ha^{-1} with 202 kg N ha^{-1}. An experiment with rice cv. Basmati 370 was conducted in sandy clay loam soil with 0, 30. 60, 90 and 150 hg N ha^{-1} and found that number of tillers/hill increased up to 16.4 and straw yield increased up to 9.1 t ha^{-1} with increasing N rate (Hussain *et al.,* 1989).

Phongpan *et al.* (1988) reported that the grain and straw yield of rice increased significantly with increasing rates of urea application. The yield of paddy increased due to application of N up to 100 kg ha^{-1} (Maskina *et al.,* 1987). BRRI (1987) observed that the highest yield of rice grain (5.7 t/ha) was obtained by the application of 120 kg N/ha.

Reddy *et al.* (1986) reported that the higher yield was obtained through the application 90 kg N/ha to rice. Idris (1981) reported that the grain yield of all cultivars increased remarkably due to the application of chemical fertilizers; the yields were maximum with the maximum dose of N (120 kg N/ha) but with variable dose of P_2O_5.

Straw yield of a crop is closely related to the vegetative growth viz. plant height, tiller numbers, leaf numbers and final stand of a crop (Singh and Verma, 1971). The beneficial effect of any treatment on one or more of these characters without a corresponding decrease in one or more of them will result in increased straw yield. In the present investigation, the N application through any means enhanced the growth attributes that ultimately led to higher straw yield.

2.3 Interaction effect of organic manure and chemical fertilizers on the growth and yield of rice

Arif *et al.* (2014) showed that organic and inorganic manures in combination increased the plant height, fertile tillers per hill, number of grains per panicle, panicle length, number of panicles per hill, 1000-grain weight, biological yield, grain yield and harvest index. Maximum number of fertile tillers per plant (16.79), number of panicles per hill (8.41), 1000- grain weight (21.12 g), biological yield (10.19 t/ha), grain yield (4.47 t ha^{-1}) and harvest index (43.76%) were recorded from the plots receiving poultry manure @ 10 t ha^{-1} in combination with 50% of recommended dose of fertilizer. It is evident that yield of rice can be increase significantly with the combined use of organic manure with chemical fertilizers.

Dekhane *et al.* (2014) conducted an experiment to assess the performance of different organic and inorganic fertilizer on growth and yield of paddy crop

(Variety GR 11) during Kharif season. Different doses of fertilizers were applied to all the plots except untreated control. Application of 50 % N through RDF + 50% N through vermicompost recorded higher growth attributes like plant height was 42.2 cm and 118.1 cm, No. of tillers per plant was 8.7 and 12.1 at 45 DAT and at harvest time respectively, panicle length (22.3 cm), grains per panicle (128.0), 1000-grain weight (19.7 g) and grain yield (4.97 t/ha.) and straw yield (5.77 t/ha.) of rice variety GR 11. The data clearly revealed that the yield obtained with treatment T5 (50% RDF + 50% N through vermicompost) was recorded significantly higher growth as well as yield attributes than all other treatments.

Issaka *et al.* (2014) conducted an experiment to examine the effects of inorganic fertilizer (IF), poultry manure (PM) and their combinations on rice yield and possible residual effects. Grain yield of IF was similar to grain yield of PM/IF combinations. The results indicate that integrating IF and PM is a better option in increasing and sustaining rice production.

Kumar *et al.* (2014) reported that application of organic and inorganic sources of nutrient in combination remarkably increased yield, yield attributes and nutrient uptake of rice than alone. 125% RDF + 5 t ha^{-1} vermicompost recorded significantly higher yield, yield attributes and nutrient uptake in comparison to other treatments and this was followed by 100% RDF + 5 t ha^{-1} vermicompost. 125% RDF + 5 t ha^{-1} vermicompost was increased the number of panicles (20.50%), panicle length (23.12%), panicle weight (13.02%), 1000 grain weight (12.90%), grain yield (31.15%), straw yield (37.12%), protein content (18.77%), N uptake in grain (36.81%) and straw (42.81%), P uptake in grain (32.62%) and straw (31.56%) and K uptake in grain (35.46%) and straw (25.39%) over control. The lower yield, yield attributes, gross return and nutrient uptake was recorded in control.

Singh *et al.* (2014) conducted an experiment to study the effect of integrated nutrients management on soil fertility and productivity of rice. Significantly higher growth and yield were recorded with 50% N through urea+50% N through FYM. The combined application of fertilizer-N and FYM sustained the productivity even at lower rate of fertilizer-N application. The highest NPK and S uptake was recorded with 50% N substituted by FYM followed by 75% N through urea+Azola with PSB and minimum with control. The improvement of soil fertility observed with respect to organic carbon, available NPK and S was prominent with the application of 50% N through urea and 50% N through FYM. Sujatha *et al.* (2014) reported that application of different organic sources had no significant effect on the harvest index of rice crop.

Siam *et al.* (2014) indicated that all the used fertilizer treatments i.e. inorganic fertilizer, organic fertilizer and their combination significantly increased the growth parameters, straw and Grain yields of both rice varieties compared with those obtained under non fertilizer treatment. Inorganic fertilizers treatment significantly increased the growth parameters and yield of rice as compared with those obtained by using the organic fertilizer treatment. The highest values of the growth parameters and yield were obtained by using the organic and inorganic fertilizer in combination followed by the two rates of inorganic fertilizer treatments and organic fertilizer alone in descending order.

Egbuchua and Enujeke (2013) conducted an experiment to evaluate the effects of organic and inorganic fertilizer on the yield and yield components of rice. The results showed that 10 t ha^{-1} treatment applications gave the highest values in plant height (75.45 cm), straw and grain yield 534.20 and 625.03 kg ha^{-1} and 1000 grain weight 42.7 g ha^{-1}. There was a synergistic effect of organic and inorganic fertilizer in all growth and yield parameters evaluated.

Garai *et al.* (2013) conducted a field trial during 2009 to 2011 to study the effect of inorganic fertilizer and vermicompost on the yield of Boro rice and its impacts upon soil nutrient status and grain uptake. The highest yield attributes were recorded with full recommended dose of inorganic fertilizer along with vermicompost at 2.5 t ha^{-1} which was at par with 75% of inorganic fertilizer along with vermicompost at 2.5 t ha^{-1}.

Islam *et al.* (2013) reported that yield contributing characters and yields were significantly influenced by applied fertilizer and manure. The (50% RDCF + 4 ton poultry manure/ha) showed the highest effective tillers/hill, plant height, panicle length, 1000 grain wt., grain yield (5.92 kg/plot) and straw yield (5.91 kg/plot). The higher grain and straw yields were obtained organic manure plus inorganic fertilizers than full dose of chemical fertilizer and manure. The highest concentrations of grain and straw N, P, K, S were recorded in (50% RDCF + 4 ton poultry manure/ha) treatment. The levels of organic matter and nutrient concentration were increased in the post-harvest soils due to added manure plus inorganic fertilizer.

Ranjitha *et al.* (2013) conducted a field experiment during kharif 2010 at Directorate of Rice Research farm, Rajendranagar, India. They found that, application of 50 percent recommended dose of nitrogen (through urea) and remaining 50 percent RDN through vermicompost resulted in significantly higher grain (5520.8 kg ha^{-1}) and straw yield (6264.9 kg ha^{-1}) in addition to nutrient uptake (157.9, 30.7 and 166 N, P and K kg ha^{-1} respectively).

Tilahun-Tadesse *et al.* (2013) revealed that applying FYM at 15 t ha^{-1} combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} increased grain yield by 123% and 38% compared to the negative (0-0-0 kg ha^{-1} FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively. Similarly; LAI, CGR, NAR, the number of filled spikelets per panicle, N and P uptake, biomass yield, and grain protein content as well as agrophysiological efficiency of N and P were significantly enhanced in response to increasing the rates of FYM and inorganic N and P fertilizers. It was observed that 15 t ha^{-1} FYM combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} resulted in the maximum grain yield.

Malviya *et al.* (2012) conducted a field experiment during rainy (kharif) season of 2007 and2008 at Jabalpur, M.P. to study the combined effect of different proportions of vermicompost and fertilizers on growth and yield of scented rice. Application of 100% NPK through fertilizers significantly influenced the growth and yield attributes of rice compared with application of vermicompost alone and different combination of vermicompost and inorganic fertilizers. The grain and straw yields were recorded highest with recommended dose of fertilizers closely followed by the substitution of proportions of NPK proportions (20% and 40% N) with vermicompost. The NPK uptake was maximum with the recommended dose of fertilizers.

Santai *et al.* (2011) and Sarwar*et al.* (2008) reported that vermicompost along with full recommended dose of chemical fertilizer improved most of the rice characters. Siavoshi *et al.* (2011) revealed that grain yield and its components were significantly increased in all the treatments over control. The maximum grain yield in 2008 (4335.88 kg/ha) was noted in plants treated with 2 t ha^{-1} organic fertilizer and it was (4662.71 kg ha^{-1}) for 2009 for plant treated with combination of chemical fertilizer + 1.5 t ha^{-1} organic fertilizer. An increase in the grain yield at the abovementioned treatments was 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.

Ande *et al.* (2010) have also reported better performances of maize and other cereals when treated with combined use of organic and inorganic fertilizers. Ali *et al.* (2009) conducted a field experiment to evaluate the suitability of different sources of organic materials for integrated use with chemical fertilizers for the Boro-Fallow-T. Aman rice cropping pattern. Application of 70% NPKS + PM produced the highest grain yield of T. Aman rice, which was identical to that obtained with 100% NPKS with no manure. In Boro season, application of 100% NPKS produced the highest grain yield of 6.87 t ha^{-1}, which was identical with the application of 70% NPKS + PM (6.57 t ha^{-1}). The total grain yield in the cropping pattern ranged from 5.14 t ha^{-1} in control treatment to 12.29 t ha^{-1} in the 100% NPKS. The application of 3 t ha^{-1} PM with 70% NPKS produced the total yield of 12.09 t ha^{-1} followed by 11.59 t ha^{-1} in the treatment containing 10 t ha^{-1} MBR plus 70% NPKS. It appears that the application of 3 t ha^{-1} PM once in a year with 70% NPKS can reduce the use of 30% NPKS as fertilizers. There were negative balances for N and K with the highest mining.

Ojeniyi *et al.* (2009) reported an increase in plant height, leaf area, grain yield, cob and ear weight of cereals treated with organic and inorganic fertilizer. Rahman*et al*. (2009) conducted a field experiment to study the effect of urea N in combination with poultry manure and cowdung in rice and found application of manures and different doses of urea N fertilizer significantly increased the yield components and grain and straw yields.

Xu *et al.* (2008) observed that application of half inorganic fertilizer and half organic manure increase nutrient absorption, panicle number, yield of rice & also increased soil organic matter. Sharma *et al.* (2008) observed best growth and yield attributes of rice by vermicompost along with 100% recommended dose of chemical fertilizer. Fashola and Ogungbe (2007), Akanbi *et al.*, (2010), Olatunji and Ayuba (2011) in their different fertilizer treatment studies on different crops, reported that crops that received the combination of organic and inorganic fertilizers performed better in all growth and yield components.

Nayak *et al.* (2007) reported that application of compost and inorganic fertilizer increased microbial growth in soil, vegetative growth and maximum tillering of rice. Miah *et al.* (2006) stated that an application of poultry manure with soil test basis (STB), IPNS and AEZ based fertilizer gave higher grain yield compared to other organic materials. Barik *et al.* (2006) reported half of the recommended dose of chemical fertilizer (NPK) along with vermicompost at 10 t ha^{-1} recorded higher grain yield of rice than at full dose of chemical fertilizer (NPK) only.

Sing *et al.* (2005) stated the effect of integrated management of N fertilizer, vermicompost and azolla on grain yield and nutrient uptake of rice and on soil fertility. The highest grain straw yields were recorded with the application of 60 kg N ha^{-1}. They also found the highest N, P, and K uptake with the application of 60 kg N ha^{-1} plus azolla treatment. Tripathy *et al.* (2004) found significantly higher seed yield under the residual effects of the blended cowdung and NPK fertilizer compared to the control.

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

Miah *et al.* (2004) found 5.6-6 t ha^{-1} grain yields with application of 2 t/ha poultry manure plus 120 kg N/ha in Boro season. Saleque *et al.* (2004) showed that application of one third of recommended inorganic fertilizers with 5 t cowdung increased the low land rice yield than other treatments and gives yield 8.87 t ha^{-1}. Davarynejad *et al.* (2004) conducted an experiment to investigate the effect of manure and municipal compost and their enrichment with chemical fertilizers on growth and yield of rice. Results showed that compost alone did not increase grain yield. However, when enriched with different levels of chemical fertilizer the highest amount of grain yield was produced. The yield was comparable to the yield obtained from 40 t ha^{-1} of compost. This indicated that compost might be an appropriate substitute for manure and half of chemical fertilizer needed for soil. Miah *et al.* (2004) observed that 5.6-6 t ha^{-1} grain yield with application of 2 t ha^{-1} poultry manure plus 120 kg N ha^{-1} in Boro season. Kaleeswari and Subrabmanian (2004) found that organic manures at 12.5 t ha^{-1} and inorganic phosphatic fertilizer i.e. single super phosphate (SSP) and udaipuer rock phosphate (RUP) at 0, 30, 60 kg P ha^{-1} combined with organic manure at 12.5 t $ha^{-1}$and inorganic P fertilizers recorded the highest grain yields and N, P, and K uptake by rice.

The combined application of organic and inorganic N sustained the productivity. Soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizer alone. The highest grain yields of Rabi sorghum and chickpea were obtained with 50percent N through green manure plus 50 percent fertilizer N (Tolanur and Badanur, 2003).

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

Channabasavanna (2003) conducted a field experiment to evaluate the efficient utilization of poultry manure with inorganic fertilizers in wetland rice and found that the grain yield increased with each increment of poultry manure application and was maximum at 3 t poultry manure/ha. Poultry manure at 2 t ha^{-1} recorded significantly higher values for seed yield and its attributes. The study proved the superiority of poultry manure over farmyard manure (FYM). It was evident from the study that one ton of poultry manure was equivalent to 7 ton FYM which produced at per seed yields. Agronomic efficiency of N (AEN) at 75% NPK (112.5:56.3:56.3 kg NPK/ha) was equivalent to 2 t poultry manure/ha. The results showed that an increase in poultry manure and fertilizer increased rice seed yield. The AEN decreased with an increase in the application of poultry manure and NPK fertilizer. Adeniyan and Ojeniyi (2003) have also reported that balanced plant nutrition and enhanced crop production are ensured with the use of organic and inorganic fertilizer.

Sinha *et al.* (2002) showed that application of BGA in combination with 90 kg N ha^{-1} recorded favorable results in all three rice cultivars (Saryu-52, Swarna and Jaya) and was comparable with grain and straw yield at recommended dose of 120 kg n ha^{-1}. The response of BGA in combination with green manure was very much pronounced at 30 kg N ha^{-1} and was comparable to individual application of inorganic N at 90 and 120 kg ha^{-1} while maximum yield was recorded at 60 kg N ha^{-1}. Residual effect of grain green manure and BGA also observed in wheat crops with Azotobacter at all levels of N. Maximum yield was recorded at 90 kg N ha^{-1} + Azotobacter.

A field experiment was conducted in Orissa, India during the Kharif season of 1999 to determine the effect of integrated application of vermicompost and chemical fertilizer on rice cv. Lalat. Yield components were increased by integrated application of vermicompost and chemical fertilizers compared to the other treatments. The highest results in terms of straw and crop yields were obtained with 50% vermicompost + 50% chemical fertilizers (Das *et al.*, 2002).

A study was conducted on two wheat cultivars to investigate the effect of chemical fertilizers (NPK fertilizers) and organic manure (vermicompost). Results showed that plant height, dry matter production and grain yield were higher at higher dose of vermicompost. Number of tillers and leaves per plant were very low at early stages of growth and suddenly increased after adding different doses of vermicompost and organic manure (Khandal and Nagendra, 2002).

Vanju and Raju (2002) conducted a field experiment on integrated nutrient management practice in rice crop. Different combinations of chemical fertilizer with poultry manure (PM) 2 t ha^{-1} gave highest grain and straw yield. Ahmed and Reddy (2002) conducted a field experiment to optimize fertilizer recommendation of N, P and K through chemical fertilizers, FYM and GM using soil test values. They recommended 3 doses, viz, inorganic fertilizers alone, inorganic + FYM, and inorganic + GM for attaining 35 and 45 q/ha of rice in alluvial soils.

Chettri *et al.* (2002) conducted an experiment on rice cultivation under chemical fertilizer with or without FYM. They found that the highest number of effective tillers, grains per panicle, percentage of filled grains, 1000-grain weight and grain yield (44.05 q/ha) where obtained from the application of 60,3 and 10 kg N, P_2O_5, K_2O with FYM/ha. Satyanarayana *et al.* (2002) carried out an experiment on integrated use of organic and inorganic fertilizers. It was obtained that the application of FYM at 10 t/ha and inorganic fertilizer at 120:60:45 kg N: P_2O_5: K_2O/ha increased grain and straw yields, tiller number, filled grains per paincle, and 1000- grain weight.

Rahman (2001) conducted experiment with rice (Boro and T. Aman) with N, P, K, and Zn fertilizers alone with organic manures (cow dung and green manure). The findings of his experiment suggest that he integrated use of fertilizers with manure (viz. sesbania, cow dung) can be an efficient practice for ensuring higher crop yields without degradation of soil fertility.

Sing *et al.* (2001) reported the integrated effect of chemical fertilizer (NPK) with farm-yard manure (FYM) and Blue Green Algae (BGA) on grain yield and nutrient availability in tropical area. Both rice and wheat yield continued significantly with increasing NPK level up to 100% of the recommended rate.

However maximum yields of rice and wheat were obtained where recommended rate of NPK was applied along with FYM and BGA. Available soil nutrients enhanced up to rates of 75% of the recommended NPK dosages alone or with FYM, BGA or FYM + BGA, compared with initial 66 t ha^{-1} was incorporated into the soil and then wheat was grown. The result indicated that the various application rates were significantly correlated with improvement in physical properties of soil as well as straw and grain yields of rice.

Tiwari *et al.* (2001) found that the effect of Farm Yard Manure (FYM), biocides (bitachlor, BHC (HCN) and Ziram) and cyanobacteria (BGA) together with recommended doses of N, P and K on biodiversity of microbial lead, biological yield, quality of rice seeds, nutrient uptake and soil productivity. Maximum yield of rice was obtained with the treatment receiving 10 t FYM ha^{-1} plus BHC and algal inoculation. Ranjha *et al.* (2001) carried out an experiment about rice response to applied nutrients. The combination N,P,K and Zn+FYM resulted in the greatest plant height (99.29 cm), grains per panicle (111,33), thousand –grain weight (19.47 g), grain yield per pot (53.67 g) and straw yield per pot (57.73g).

Babu *et al.* (2001) showed significant influence on number of tillers per hill due to individual and combined application of organic manures (FYM, green manure and press mud) along with inorganic fertilizer. Ranjha *et al.* (2001) reported that the response of rice to Zn, P and FYM was studied in green house by using sandy clay loam soil. Different combinations of N, P, K and Zn were applied at the rate of 120-80-60 and 20 kg ha^{-1} along with FYM at the rate of 12 Mg ha^{-1}. All the growth parameters of rice increased with P application over control. Paddy and straw yields produced maximum by the application of FYM along with NPK + Zn. Nitrogen, P and K contents increased with the application of NPK fertilizer along with FYM and Zn but there was significant decrease in P contents by the application of Zn. Zinc contents were found maximum in those treatments where Zn and Zn + P were applied with NPK. The post-harvest soil analysis showed that

NPK contents were higher in pots with FYM incorporation but Zn was high in pots treated with $ZnSO_4$.Chitdeshwari and Savithri (2000) carried out a pot experiment to determine the effect of eight organic and inorganic fertilizers for growth and yield of rice. It was observed that the highest yield was found by green manure (6.25 t ha^{-1}) application.

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

Aulakah *et al.* (2000) found that integrating fertilizer N (FN) with legume green manures (GM) application @ 60 kg FN ha^{-1} (FN 60) and 20 kg GM ha-1 (GM 20) rice yield was double the control yield and 6% greater than the FN 120 treatments.

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

Anand Swarup Yaduvanshi (2000) reported that continuous use of fertilizer N and P in alkali soils significantly enhanced the yield of rice. The maximum yield was obtained with 100% NPK plus GM (Green Manure). He also found that application of 100% NPK plus organic manure was significantly better than 150% NPK. Marginal improvement of N< P< and K status occurred with 100% and 150% NPK treatments.

The significant influence of organic and inorganic fertilizer on some growth and yield components could be attributed to the synergistic effects of the treatment in rice physiological processes, restoring soil quality and increasing yield by the combination of the two nutrient sources (Brady and Weil, 1999). Application of 50 kg N with green leaf manure increased the grain and straw yield in two seasons (Chittra and Janaki, 1999).

Salik (1999) observed a field investigation during the season of 1995 and 1996, rice was grown with difference combinations of poultry manure, farmyard manure and green manuring with *Sesbania rotstrata* and chemical nitrogen fertilizer (Urea) in 50:50 ratios. The grain yield, straw yield, gross return, net return and net return per rupee investment were higher when different types of organic amendments were applied than where nitrogen was applied as urea alone.

Muthukrisnan *et al.* (1998) reported that the application of 100% or 133% of the recommended mineral fertilizer (150: 60: 60: N: P: K) and 10 t farmyard manure with or without adjustment with mineral fertilizer, 21 kg $ZnSO_4$ and foliar spraying of 1% KCl in irrigated rice. The maximum rice (cv. ADT 38) yield was recorded with normal plant population of 500000 plants ha^{-1} (20 × 10 cm spacing) and application of organic manure adjusted with mineral fertilizer.

Misra andsharma (1997) stated that the continuous addition of NPK fertilizers showed no deteriorating effect on soil physical properties; rather it significantly increased aggregation and water transmission characteristics and reduced bulk density and penetration resistance of the soil. The effectiveness of manures on aggregation, water transmission and hardness of the soil was observed. Grain yield of rice, wheat and winter maize crops were also enhanced significantly with continuous application of NPK fertilizer, farmyard manure and cyanobacteria separately as well as combination. Mathew and Nair (1997) carried out a trial with applied organic fertilizer alone or in combination with NPK fertilizers. They revealed a significant improvement of soil productivity and yield properties.

Pathak and sarkar (1997) studied the effect of rice straw in combination with different proportion of urea in supplying nitrogen in rice wheat cropping sequence. Straw and urea combination registered lower grain yield of rice than registered use of conventional manure and urea. A very high dose of urea with rice straw was necessary to get good yield. At early growth stage of rice, straw-urea materials recorded higher N uptake but they failed to compete with in later stage. Use dhaincha plus urea in an appropriate ratio was found to be the best in terms of yield and N uptake by rice. Beneficial effect of rice straw was not observed in succeeding wheat crops.

David and Biswas (1996) found that when 10 t PM ha^{-1} was applied with 120 kg P_2O_5nmha^{-1} then the dry matter yield of wheat and total P uptake were increased. P utilization was increased when PM was applied with mineral P. Dry matter yield was highest with 120 kg P_2O_5 with 10 t PM ha^{-1}. Grain yield and nutrient uptake of rice increased significantly with the application of vermicompost and inorganic fertilizer in a rate of 15 kg N from vermicompost supplemented with 45-13-25 kg NPK ha^{-1} with a yield of 4.06 and 5.31 t ha^{-1} (Banik and Bejbaruah, 1996).

Raman *et al.* (1996) carried out a field trial during 1984-94 with inorganic and organic inorganic nutrient supply system on rice-wheat cropping system. They observed that in the first year yield was highest with organic fertilizers only. After 2-3 years, the combination of organic and inorganic fertilizers gave similar yields to the inorganic treated plots, while after 3-4 years the combined fertilizer started giving higher yield than the inorganic source.

Singh *et al.* (1996) conduct a field experiment in Ludhiana, Punjab, India, where irrigated rice was given 60,120 or 180 kg N/ha/yr as poultry manure, urea or poultry manure + urea. In the first year, poultry manure did not perform better than urea but in the third year, 120 and 150 kg N as poultry manure produced significantly higher grain yields than the same rates as urea. Poultry manure sustained the grain yield of rice during the three years while the yield decreased with urea.

Sing *et al.* (1996) carried out a field experiment in India where irrigated rice was given 60.80 or 120 kg N ha^{-1} yr^{-1}as poultry manure +urea. In the first year poultry manure did not perform better than urea but in the fourth year 120 and 150 kg N as poultry manure produced significantly higher grain yield than the same rates as urea. The PM helped to sustain the grain yield of rice during the 3 years while the yield decreased with urea application.

Kumar and Yadav (1995) studied the effect of organic manure, fertilizers and their integrated use in rice-wheat cropping cropping sequence. In the first year, 25-50% substitution of fertilizers through organic source, FYM, GM, and wheat straw reduced the rice yield by 6-23% compared with 100% chemical fertilizers alone. In the following year, 25-50% N through FYM or GM along with 50-75% fertilizers to rice gave either equal or more yields compared with 100% NPK. The FYM and GM were found superior to wheat straw with respect to grain yield and NPK uptake.

Gupta *et al.* (1995) reported that the highest yield of rice was obtained with the combined application of poultry manure and P. In addition, the concentration of phosphorus in rice tissue at different stages and P uptake at maturity, increased with the application of P and/or manure. They also stated that the highest uptake P was recorded with combined application of poultry manure and P.

Islam (1995) carried out an experiment with different doses of fertilizer-N, cowdung and fertilizer *Sesbania*, and reported a significant yield increase with fertilizer-N, cowdung compared to fertilizer-N alone in T. aman rice. Zaman *et al*. (1995) reported that the application of Sesbania @ 5 t ha^{-1} (oven dry basis) once a year prior to wet season planting along with 140 kg urea N ha^{-1} yr^{-1} (80 kg for dry season and 60 kg for wet season) and recommended doses of P, K and S gave yield of about 11 t ha^{-1} yr^{-1} in a rice-rice cropping pattern on a moderate fertile soil. This practice allowed a saving of 150 kg urea ha^{-1} yr^{-1}.Kamiyama*et al.*

(1995) reported that an application of chemical fertilizers with F'YM produced the highest grain yield of rice.

Islam (1994) found a significant yield increase with fertilizer-N plus cow dung compared to fertilizer-n alone in T. Aman rice. In the following Boro rice, the yields with fertilizer-N + residual of cow dung were higher than the fertilizer-N alone.

Bhandari *et al*. (1992) observed a four year study on integrated nutrient management in a rice-wheat system that both rice and wheat yields continued to increased significantly with increasing NPK levels up to 100% of recommended dose through fertilizer GM with 50% recommended dose of NPK to rice produced as much as rice yield of 6.27 t ha^{-1} to 100% NPK dose through fertilizer produced 6.28 t ha^{-1}. They also reported that inclusion of short duration of pulse crop (mungbean) in the system obtained 50% of recommended NPK fertilizers in rice. Among different organic source of N for rice, GM was found significantly superior to FYM and wheat straw in increasing the crop yield and nutrient uptake. Hundal*et al*. (1992) studied the contribution of GM (Green Manure)to P nutrition of rice and showed that fertilizer P addition increased dry matter production and P uptake by rice. Grain yield and P uptake by rice were highest in cowpea plots followed by dhaincha and sun hemp.

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

Ayoola and Makinde (2009) concluded that after two years of application and cropping, enriched poultry manure increases soil N, P and K contents by 41.7%, 1.8% and 20.7%, respectively while fortified cowdung increases the nutrients by 25%, 0.33% and 3.4%, respectively, Although both organic manures increased the soil N and P, poultry manure gave higher values while the soil K, Ca and Mg contents were more increased with the cowdung than poultry manure. Xu *et al.*

(2008) reported that application of chemical fertilizer with organic manure increase soil organic matter.

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

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

Bahman *et al.* (2004) conducted an experiment to observe the residual effects of N-and P-based manure and compost applications on corn grain yield and N uptake lasted for at least one growing season while the effects on soil properties were longer lasting. Soil P can contribute to crop P uptake for> 4 yr after N-based manure of compost application had ceased. Effects of manure and compost applications significantly increased soil electrical conductivity and pH levels and plant-available P and NO3-N concentrations.

Vermicompost contain more organic matter, N, P, S, Ca and Mg. it was shown that worm worked composts have better texture and soil enhancing properties, hold typically higher percentages of N, P and K (Zahid, 2001).

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

Aggelides and Londra (2000) conducted that the amendment compost improved all physical properties under consideration in the soils. The improvements were proportional to the compost rate. The results supported the bulk density and penetration resistances were reduced. The reduction was greater in the loamy soil than in the clay soil. Mean weight diameter of the aggregates was reduced in both soils, while aggregate stability was increased.

The literature review discussed above indicates that organic manure can supply a good amount of plant nutrients and thus can contribute to crop yields. The properties of soils are also influenced by the inclusion of organic manure and crop residues in the soil fertility management system either directly or through residual action. The integrated approach by using the organic and inorganic sources of nutrients helps improve the efficiency of nutrients. Hence, an effort should be undertaken to investigate the effect of integrated nutrient management on substance of crop productivity and maintenance of soil fertility in a rice cropping.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter includes a brief description of the experimental soil, site and location, rice variety, land preparation, experimental design, treatments, cultural operation, collection of soil and plant samples etc. and analytical methods followed in the experiment to study the effect of vermicompost and N, P, K, S on the growth, yield and yield contributing characters of rice.

3.1 Location

The field experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2013 to June 2014. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude (Google maps, 2014) at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract (BBS, 2011). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2 Soil

The soil of the experimental site was medium high land with deep red brown terrace soil. The pH value of the soil was 5.7. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. A composite soil sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The morphological, physical and chemical properties of the experimental soil have been shown in Appendix IIA, IIB and IIC.

3.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The weather data during the study period at the experimental site are shown in Appendix III.

3.4 Description of the rice variety

BRRI dhan29 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 90-2 and BR51-46-5 in 1994. It is recommended for boro season. Average plant height of the variety is 90-95 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days completing its life cycle with an average grains yield of 7.0-7.5 t/ha (BRRI, 2004).

3.5 Raising of seedling

The seedlings of rice were raised in the wet bed methods. The seed bed selected for the experiment was opened by hand spade on 25th November 2013. Seeds (95% germinated) 5 kg ha^{-1} were soaked and incubated for 48 hours. The seeds were sown on 4th December 2013 in well prepared seed bed. During seedling growth no fertilizer was used. Proper water and pest management practices were followed whenever required.

3.6 Land preparation

Land was prepared for the cultivation of BRRI dhan29. First it was ploughed with a power tiller. The soil was saturated with adequate supply of irrigation water and finally prepared by successive ploughing and cross ploughing followed by laddering. The unexpected residues were removed from the experimental plot. Finally, the land was leveled and the experimental plot was partitioned into unit plots in accordance with experimental design mentioned in the following section (3.6)

3.7 Design and Layout

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The entire experimental area was divided into 3 blocks representing the replications to reduce soil heterogeneity. The total number of plots was 48, each measuring 2 m ×2 m (4 m^2). The treatment combinations of the experiment were assigned at random into 16 plots of each block. The distance maintained between two plots was 0.5 m and between blocks was 1 m. A layout of the experimental plot is given on Plate 1.

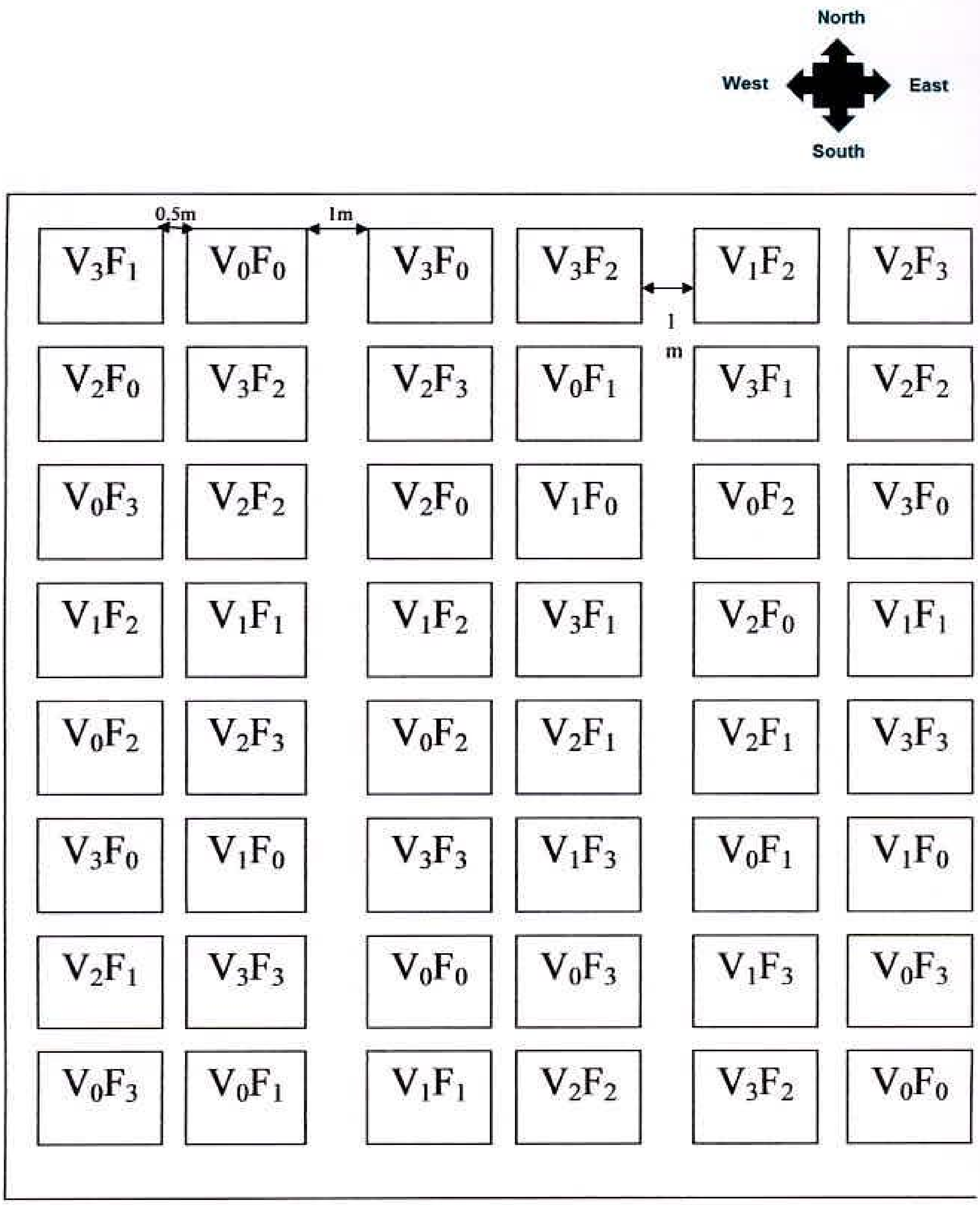


Plate 1. Layout of the experimental field

3.8 Treatments

The experiment consists of two Factors i.e. vermicompost and NPKS fertilizer each having four levels. Details of factors and their combinations are presented below:

Factor A: Vermicompost level (4)

V_0= 0 t ha^{-1} (No vermicompost)

V_1 = 1 t ha^{-1} vermicompost

V_2 = 2 t ha^{-1} vermicompost

V_3 = 4 t ha^{-1} vermicompost

Factor B: Fertilizer level (4)

F_0 = 0 kg N ha^{-1} + 0 kg P ha^{-1} + 0 kg K ha^{-1} + 0 kg S ha^{-1} (No NPKS)

F_1= 50 kg N ha^{-1} + 8 kg P ha^{-1} + 33 kg K ha^{-1} + 6 kg S ha^{-1} (Low NPKS)

F_2= 100 kg N ha^{-1} + 16 kg P ha^{-1} + 66 kg K ha^{-1} + 12 kg S ha^{-1} (Medium NPKS)

F_3= 150 kg N ha^{-1} + 24 kg P ha^{-1} + 99 kg K ha^{-1} + 18 kg S ha^{-1} (High NPKS)

Treatment Combinations

V_0F_0 = Control (No vermicompost + No NPKS)

V_0F_1 = (No vermicompost + Low level of NPKS)

V_0F_2 = (No vermicompost + Medium level of NPKS)

V_0F_3 = (No vermicompost + High level of NPKS)

V_1F_0 = (1 t ha^{-1} vermicompost + No NPKS)

V_1F_1 = (1 t ha^{-1} vermicompost + Low level of NPKS)

V_1F_2 = (1 t ha^{-1} vermicompost+ Medium level of NPKS)

V_1F_3 = (1 t ha^{-1} vermicompost + High level of NPKS)

V_2F_0 = (2 t ha^{-1} vermicompost + No NPKS)

V_2F_1 = (2 t ha^{-1} vermicompost + Low level of NPKS)

V_2F_2 = (2 t ha^{-1} vermicompost +Medium level of NPKS)

V_2F_3 = (2 t ha^{-1} vermicompost + High level of NPKS)

V_3F_0 = (4 t ha^{-1} vermicompost + No NPKS)

V_3F_1 = (4 t ha^{-1} vermicompost + Low level of NPKS)

V_3F_2 = (4 t ha^{-1} vermicompost + Medium level of NPKS)

V_3F_3 = (4 t ha^{-1} vermicompost + High level of NPKS)

3.9 Application of vermicompost and fertilizers

Fertilizers and manure were used based on Fertilizer Recommendation Guide, 2012 (BARC, 2012); the findings of previous works were kept in mind. The required amount of P, K and S fertilizers (Triple superphosphate, Muriate of Potash and Gypsum, respectively) and 40% of N (urea) were applied as per treatment combination at a time during final land preparation. The remaining 60% of N (urea) was applied in two splits at maximum tillering and panicle initiation stages, respectively. The required amounts of vermicompost as per treatment combinations were applied uniformly in the plot during final land preparation and mixed well with the soil by hand spading.

3.10 Transplanting

Thirty days old seedlings of BRRI dhan29 were carefully uprooted from the seedling nursery and transplanted on 19th January 2014 in Boro season. Two seedlings per hill were used following a line to line of 20 cm and hill to hill spacing of 15 cm. After one week of transplantation all plots were checked for any missing hill which was filled in with extra seedlings whenever required.

3.11 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.11.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within 10 days of transplantation.

3.11.2 Weeding

Weeding was done as per the experimental treatment.

3.11.3 Irrigation and drainage

The experimental plots were irrigated during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.11.4 Plant protection measures

There were negligible infestations of insect-pests during the crop growth period. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control stem borer and rice bug.

3.12 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.13 Harvest and post-harvest operation

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in color. From the centre of each plot 1 m^2 area on 29th May 2014 was harvested to determine yield of individual treatment and converted into t ha^{-1}. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after required drying in sun. Before harvesting, ten hills were selected randomly outside the sample area of each plot and harvested at the ground level for collecting data on yield contributing characters.

3.14 Collection of samples

3.14.1 Soil sample

The initial soil sample was collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Postharvest soil samples were collected from each plot separately at 0-15 cm depth on 30th May 2014. The samples were air-dried, ground and sieved through a 2 mm (10 mesh) sieve and preserved for analysis.

3.14.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at harvesting stage of crop. Ten plants were randomly collected from each plot after threshing. The plant samples were washed first with tap water and then with distilled water several times. The plant samples were dried in electric oven at 70^{0}C for 48 hours. After that the samples were ground in an electric grinding machine and stored for chemical analysis.

3.15 Collection of data

Data collection were done on the following parameters-

3.15.1 Plant height

The plant height was measured from ground level to top of the flag leaf. 10 plants were measured randomly from plot and averaged. It was done at the ripening stage of the crop.

3.15.2 Number of tillers/hill

Five hills were taken at random from each plot and total number of tillers (effective and non-effective tillers) was counted, the average of which was considered as total number of tillers per hill.

3.15.3 Panicle length (cm)

The panicle length was measured from the bottom of the end of the panicles were measured randomly from each plot and averaged.

3.15.4 Flag leaf length (cm)

The flag leaf length was measured from the bottom to the end of the tip of the leaf. The flag leaves were measured randomly from each plot and averaged. It was done at the ripening stage.

3.15.5 No. of filled/unfilled grains per panicle

It was done after harvesting, at first number of filled/unfilled grains were counted. Grains from 10 panicles were counted and averaged.

3.15.6 Thousand grain weight (g)

Thousand grains of rice were counted randomly from each plot and then weighed plot wise.

3.15.7 Grain yield

Grain obtained from $1m^2$ area from the center of each unit plot were dried, weighed carefully and then converted into t ha^{-1}.

3.15.8 Straw yield

Straw obtained from $1m^2$ of each individual plot were dried, weighed carefully and the yield was expressed in t ha^{-1}.

3.15.9 Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

3.15.10 Harvest index (%)

Harvest index is the relationship between grain yield and biological yield (Gardner *et al.*, 1985). It was calculated by using the following formula:

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.16 Chemical analysis of the straw, grain, soil and vermicompost samples

3.16.1 Chemical analysis of straw, grain samples

3.16.1.2 Collection and preparation of straw, grain samples

Grains and straw samples were collected after threshing for N, P, K and S analyses. The plant samples were dried in an oven at 65^0C for 72 hours and then ground by a grinding machine. The samples were stored in plastic vial for analyses of N, P, K and S. The grains and straw samples were analyzed for determination of N, P, K and S concentrations. The methods were as follows

3.16.1.3 Digestion of straw, grain samples with sulphuric acid for N analysis

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^0 C and added 2 ml 30% H_2O_2 then heating was continued at 360^0 C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.16.1.4 Digestion of straw, grain samples with nitric-perchloric acid for P, K and S analysis

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

3.16.1.5 Determination of P, K and S from straw, grain samples

3.16.1.5.1 Phosphorus

Grains and straw samples were digested by di-acid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grains sample and 2 ml for straw sample from 100 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.16.1.5.2 Potassium

10 ml of digest sample for the grains and 5 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.16.1.5.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grains and straw) as described by Page *et al.* (1982). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.16.2 Soil sample analysis

3.16.2.1 Soil Analysis

The initial soil sample was analyzed for particle size distribution, particle density, bulk density, pH, organic carbon, total nitrogen, available P and exchangeable K (Appendix II). Post harvest soil samples were analyzed for pH, organic matter, total nitrogen, available P, exchangeable K, available S and cation exchange capacity.

3.16.2.2 Textural class

Particle size analyses of soil was done by hydrometer method (Black, 1965) and the textural class was determined by plotting the values for % sand, % silt and %

clay to the Marshall's Textural Triangular Coordinate following the USDA system.

3.16.2.3 Particle density

Particle density of soil was determined by volumetric flask method (Black, 1965) following the formula:

$$\text{Particle density (Dp)} = \frac{\text{Weight of soil (solid)}}{\text{Volume of soil (solid)}} \times g/cc$$

3.16.2.4 Bulk density

Bulk density of soil was determined by core sampler method following the formula:

$$\text{Bulk density } (D_b) = \frac{\text{Weight of oven dry soil}}{\text{Volume of soil (solid)}} \times g/cc$$

3.16.2.5 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1934). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.16.2.6 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160^0 C and added 2 ml H_2O_2 and then heating at 360^0 C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982). Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

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

Where, T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.16.2.7 Available phosphorus

Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ at pH 8.5. The phosphorus in the extract was then determined by developing the blue colour by ascorbic acid reduction of phosho-molybdate complex and measuring the colour calorimetrically at 660 nm (Olsen *et al.,* 1954).

3.16.2.8 Exchangeable potassium

Exchangeable potassium of soil was determined from 1 N ammonium acetate (pH 7.0) extract of the soil by using flame-photometer.

3.16.2.9 Available sulphur

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

3.16.3 Vermicompost

Vermicompost sample was analyzed for organic matter, total N, available P, K and S contents following the methods used for plant and soil analysis. Vermicompost contained 11.06 % organic matter, 0.630 % total N, 0.022 % available P, 0.078 % available K and 0.031 % available S.

3.17 Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTAR IV

RESULTS AND DISCUSSION

The results of different yield attributes, yield and nutrient concentrations in the straw and grains and availability of different nutrients in the soil after harvest of rice are presented this chapter.

4.1 Plant height

4.1.1 Effect of vermicompost

Significant variation was observed on the plant height of rice when the field was incorporated with different doses of vermicompost (Appendix IV and Table 1). The tallest plant (93.89 cm) was observed from V_3 which was statistically similar (93.74 cm) with V_2. The smallest plant (90.05 cm) was observed from V_0 (control) which was statistically at par (90.14 cm) with V_1. Vermicompost might have increased the soil moisture content, soil porosity and other plant enhancing characters and for that reason increasing dose of vermicompost increased plant height. Similar result was reported by Gorlittz (1987). Agrawal *et al.* (2003) found that the increase in soil organic matter content through the application of FYM in wheat increased plant height.

4.1.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on the plant height of rice (Appendix IV and Table 2). The longest plant (94.52 cm) was observed from F_3 and the lowest (89.02 cm) was found from F_0 (control) treatment where no fertilizer was applied. Song *et al.* (2001) found that application of NPK fertilizer increased the height of wheat plant compared with control treatment. Increase in plant height in response to recommended dose of fertilizer might be primarily due to the improved vegetative growth and supplementary contribution of nitrogen (Awan *et al.* 2011).

4.1.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and fertilizer had significant effect on plant height of rice (Appendix IV and Table 3). The highest plant height (95.78 cm) was observed from V_3F_2 and it was statistically similar with V_3F_3 (95.10 cm), V_2F_3 (94.81 cm), V_0F_3 (94.67 cm), V_2F_2 (94.33 cm), V_2F_1 (93.76 cm), V_1F_3 (93.50 cm) and V_3F_1 (93.32 cm) whereas, the lowest (86.04 cm) was found from V_0F_0. The variation in plant height due to nutrient sources was considered to be the variation in the availability of major nutrients. Chemical fertilizer offers nutrients which are readily soluble in soil solution and thereby instantaneously available to plants. Nutrient availability from organic sources is due to microbial action and improved physical condition of soil. These results were supported by Sarker *et al.* (2004).

Table 1. Effect of vermicompost on plant height, effective tiller hill^{-1}, non-effective tiller hill^{-1} and flag leaf length of rice

Vermicompost	Plant height (cm)	Effective tiller hill^{-1}	Non-effective tiller hill^{-1}	Flag leaf length (cm)
V_0	90.05 b	12.11 c	2.31 a	23.23 c
V_1	90.14 b	13.01 b	2.13 ab	23.76 bc
V_2	93.74 a	13.65 a	1.61 c	24.43 ab
V_3	93.89 a	13.60 ab	1.96 b	25.04 a
$LSD_{(0.05)}$	1.275	0.6138	0.236	0.8685
CV (%)	1.66	5.62	14.14	4.32

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.2 Effective tillers hill^{-1}

4.2.1 Effect of vermicompost

Tillering is an important trait for grain production and is thereby an important aspect of rice growth improvement. Different doses of vermicompost showed significant variation on effective tillers hill^{-1} of rice (Appendix IV and Table 1).

The maximum effective tillers hill^{-1} (13.65) was obtained from V_2 which was statistically similar (13.60) with V_3 and the minimum (12.11) was recorded in V_0 (control) treatment. Effective tillering depends primarily on soil physical conditions that were superior due to addition of poultry manure (Usman *et al.* 2003).

4.2.2 Effect of NPKS fertilizer

Variation of effective tillers hill^{-1} of rice at different doses of NPKS fertilizer was significant (Appendix IV and Table 2). The maximum effective tillers hill^{-1} (14.55) was observed from F_3 and the minimum (11.41) was found in the treatment that received no fertilizer (F_0). Organic sources offer more balanced nutrition to the plants, especially micro nutrients which has caused better affectivity of tiller in plants grown with vermicompost (Miller, 2007). This result was also supported by Rakshit *et al.* (2008), Uddin *et al.* (2002), Ayoub (1999) and Chander and Pandey (1996).

4.2.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on effective tillers hill^{-1} of rice (Appendix IV and Table 3). The maximum (15.30) effective tillers hill^{-1} was observed from V_3F_2 which was statistically at par with V_2F_3 (14.97), V_3F_3 (14.87), V_1F_3 (14.43) and V_2F_2 (14.10) whereas, the lowest (10.50) was counted from V_0F_0 and it was statistically identical with V_3F_0 (10.63) and V_0F_1 (11.50). In case of control treatment there was deficiency of N and other essential nutrients which was required for tiller production while the other treatments supplied it which rendered the higher number of tillers. Nayak *et al.* (2007) reported a significant increase in effective tillers hill^{-1} due to application of chemical fertilizer with organic manure. Similar results were found by Ahmed and Rahman (1991), Aptosol (1989) and Tanaka (1968).

Table 2. Effect of NPKS fertilizer on plant height, effective tillers hill^{-1}, non-effective tillers hill^{-1} and flag leaf length of rice

NPKS Fertilizer	Plant height (cm)	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Flag leaf length (cm)
F_0	89.02 d	11.41 d	2.68 a	22.42 c
F_1	91.26 c	12.58 c	2.30 b	23.68 b
F_2	93.03 b	13.82 b	1.73 c	24.96 a
F_3	94.52 a	14.55 a	1.29 d	25.41 a
LSD $_{(0.05)}$	1.275	0.6138	0.236	0.8685
CV (%)	1.66	5.62	14.14	4.32

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.3 Non-effective tiller hill^{-1}

4.3.1 Effect of vermicompost

The significant result was found in non-effective tiller hill^{-1} of rice by the different levels of vermicompost (Appendix IV and Table 1). The maximum non-effective tiller hill^{-1} (2.31) was obtained from V_0 which was statistically similar (2.13) with V_1 and the minimum (1.61) was noted in V_2 treatment.

4.3.2 Effect of NPKS fertilizer

The significant variation was found due to the effect of fertilizers in non-effective tiller hill^{-1} of rice (Appendix IV and Table 2). The maximum non-effective tiller hill^{-1} (2.68) was obtained from F_0 and the minimum (1.29) was observed from F_3 treatment. These might be due to the higher number of tiller production hill^{-1} for higher nutrient absorption where the total non-effective tillers were also higher in number.

4.3.3 Interaction effect of vermicompost and NPKS fertilizer

Production of non-effective tiller hill^{-1} of rice was significantly affected due to the interaction effect of different doses of vermicompost and NPKS fertilizers (Appendix IV and Table 3). The maximum non-effective tiller hill^{-1} (2.88) was obtained from V_0F_0 which was statistically similar with V_2F_0 (2.77), V_1F_0 (2.70),

V_0F_1 (2.63) and V_1F_1 (2.47) whereas, the minimum (0.93) was obtained from V_3F_2 which was statistically similar with V_2F_3 (0.97), V_3F_3 (1.27) and V_1F_3 (1.30). Hossaen *et al.* (2011) reported that number of non-effective tillers per hill of BRRI dhan29 varied significantly due to the application of various organic manure and inorganic fertilizers.

Table 3. Interaction effect of vermicompost and NPKS fertilizer on plant height, effective tillers hill^{-1}, non-effective tillers hill^{-1} and flag leaf length of rice

Vermicompost × NPKS fertilizer	Plant height (cm)	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Flag leaf length (cm)
V_0F_0	86.04 h	10.50 h	2.88 a	21.51 g
V_0F_1	88.70 fg	11.50 gh	2.63 a-c	23.09 d-g
V_0F_2	90.80 d-f	12.50 e-g	2.10 d-f	23.51 d-f
V_0F_3	94.67 a	13.93 b-d	1.63 fg	24.82 b-d
V_1F_0	86.61 gh	12.10 fg	2.70 a-c	22.18 fg
V_1F_1	89.25 ef	12.10 fg	2.47 a-d	23.03 e-g
V_1F_2	91.21 c-f	13.40 c-e	2.03 d-f	24.51 b-e
V_1F_3	93.50 a-c	14.43 abc	1.30 gh	25.32 bc
V_2F_0	92.05 b-d	12.40 e-g	2.77 ab	22.95 e-g
V_2F_1	93.76 a-c	13.13 def	2.23 c-e	24.57 b-e
V_2F_2	94.33 ab	14.10 a-d	1.87 ef	24.55 b-e
V_2F_3	94.81 a	14.97 ab	0.97 h	25.67 abc
V_3F_0	91.38 c-e	10.63 h	2.37 b-d	23.02 e-g
V_3F_1	93.32 a-d	13.60 c-e	1.87 ef	24.03 c-e
V_3F_2	95.78 a	15.30 a	0.93 h	27.27 a
V_3F_3	95.10 a	14.87 ab	1.27 gh	25.82 ab
$LSD_{(0.05)}$	2.550	1.228	0.472	1.737
CV (%)	1.66	5.62	14.14	4.32

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.4 Flag leaf length

4.4.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on flag leaf length of rice (Appendix IV and Table 1). The longest flag leaf (25.04 cm) was obtained from V_3 which was statistically similar (24.43 cm) with V_2 and the shortest (23.23

cm) was found from V_0 (control) treatment and it was statistically at par (23.76 cm) with V_1.

4.4.2 Effect of NPKS fertilizer

Significant variation was observed on flag leaf length of rice at different doses of NPK fertilizer (Appendix IV and Table 2). The maximum (25.41 cm) flag leaf length was observed from F_3 (High NPK) which was statistically similar with F_2 (24.96 cm) and the lowest (22.42 cm) was observed from F_0 (control) treatment where no fertilizer was applied.

4.4.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on flag leaf length of rice (Appendix IV and Table 3). The maximum flag leaf length (27.27 cm) was observed from V_3F_2 which was statistically similar with V_3F_3 (25.82 cm) and V_2F_3 (25.67 cm) whereas, the lowest (21.51) was obtained from V_0F_0 and it was statistically similar with V_1F_0 (22.18 cm), V_2F_0 (22.95 cm), V_3F_0 (23.02 cm), V_1F_1 (23.03 cm) and V_0F_1 (23.09). Again it was observed that organic fertilizer alone and in combination with chemical fertilizers significantly increased the flag leaf length over untreated control. Similar findings are reported by Mirza *et al.* (2010). The increase in leaf number as well as size due to enough nutrition can be explained in terms of possible increase in nutrient absorption capacity of plant as a result of better root development and increased translocation of carbohydrates from source to growing points (Singh and Agarwal, 2001).

4.5 Panicle length

4.5.1 Effect of vermicompost

Different doses of vermicompost had significant effect on panicle length of rice (Appendix IV and Table 4). The highest panicle length was found from V_3 (24.52 cm) and the lowest was observed from V_0 (control) (21.73 cm) which was statistically similar with V_1 (21.87 cm). This might be due to the balanced supply of nutrients from vermicompost which enhanced panicle length.

4.5.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on the panicle length of rice (Appendix IV and Table 5). The longest panicle (25.74 cm) was observed from F_3 and the shortest (21.47 cm) was recorded from F_0 (control) treatment where no fertilizer was applied. Mondal *et al.* (1987) also reported that panicle length increased with the application of N and/or K_2O. These might be due to higher absorption of different fertilizer by the plant that favored to produce the longer panicle.

4.5.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and fertilizer had significant effect on panicle length of rice (Appendix IV and Table 6). The highest panicle length (27.30 cm) was observed from V_3F_2 and the lowest (19.86 cm) was recorded from V_0F_0. Increase in panicle length in response to combined use of organic and inorganic fertilizers is might be due to more availability of macro as well as micro nutrients (Awan *et al.* 2011). Rahman *et al.* (2009), Reddy *et al.* (2005), Babu *et al.* (2001), Hoque (1999), Ahmed and Rahman (1991) and Apostol (1989) also reported similar results.

Table 4. Effect of vermicompost on panicle length, number of filled grain panicle^{-1}, unfilled grains panicle^{-1} and 1000-grain weight of rice

Vermicompost	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)
V_0	21.73 d	149.8 c	21.93 a	21.89 b
V_1	22.67 c	165.9 bc	20.92 ab	22.27 ab
V_2	23.77 b	167.3 b	20.65 b	22.33 ab
V_3	24.52 a	185.2 a	18.99 c	22.88 a
$LSD_{(0.05)}$	0.4687	17.02	1.108	0.921
CV (%)	2.43	12.12	6.45	4.95

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.6 Filled grain panicle^{-1}

4.6.1 Effect of vermicompost

Filled grain panicle^{-1} of rice was significantly influenced by different doses of vermicompost (Appendix IV and Table 4). The highest filled grain panicle^{-1} (185.2) was found from V_3 and the lowest (149.8) was observed from V_0 (control) which was statistically similar (165.9) with V_1. Maximum grains panicle^{-1} in V_3 treatment might be due to availability of macro as well as micro plant nutrients with the addition of organic matter to the soil (Siavoshi *et al.*, 2011).

4.6.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer had showed significant variation on filled grain panicle^{-1} of rice (Appendix IV and Table 5). The maximum filled grain panicle^{-1} (193.7) was found from F_3 (High NPK) which was statistically similar (179.8) with F_2 (Medium NPK) and the minimum (134.5) was obtained in F_0 (control) treatment where no fertilizer was applied. Setty and Channabasavanna (1990) observed more number of filled grains per panicle when nitrogen was supplemented through inorganic fertilizer by 75% and glyricidia or rice straw by 25%.

4.6.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and NPKS fertilizer had significant effect on filled grains panicle^{-1} of rice (Appendix IV and Table 6). The maximum (200.4) filled grain panicle^{-1} was observed from V_3F_2 and it was statistically similar with V_3F_3 (196.8), V_1F_3 (195.7), V_2F_3 (194.4), V_0F_3 (188.0), V_3F_1 (184.9), V_2F_2 (178.9) and V_1F_2 (178.8) whereas, the minimum (102.7) was observed from V_0F_0 which was statistically similar with V_2F_0 (133.9). Naing *et al.* (2010) stated that the potential number of grains per panicle was influenced by the plants' nutritional status. They further reported that combined application of 10 t

ha^{-1} FYM with 50-22 kg N-P ha^{-1} resulted in a 30.7% increase in rice filled grains number per panicle as compared to no fertilizer application. Grains/panicle significantly increased due to the application of organic manures and chemical fertilizers (Razzaque, 1996). These results are also in agreement with Hoque (1999).

Table 5. Effect of NPKS fertilizer on panicle length, number of filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-grain weight of rice

NPKS fertilizer	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)
F_0	21.47 c	134.5 c	25.11 a	21.03 b
F_1	21.87 c	160.2 b	21.38 b	22.36 a
F_2	23.61 b	179.8 a	17.42 d	22.75 a
F_3	25.74 a	193.7 a	18.60 c	23.23 a
$LSD_{(0.05)}$	0.4687	17.02	1.108	0.921
CV (%)	2.43	12.12	6.45	4.95

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.7 Unfilled grains panicle^{-1}

4.7.1 Effect of vermicompost

Unfilled grains panicle^{-1} of rice was significantly influenced by different doses of vermicompost (Appendix V and Table 4). The highest unfilled grains panicle^{-1} (21.93) was found from V_0 which was statistically similar with V_1 (20.92) and the lowest (18.99) was observed from V_3 treatment.

4.7.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer had showed significant variation on unfilled grain panicle^{-1} of rice (Appendix V and Table 5). The maximum unfilled grain panicle^{-1} (25.11) was observed from F_0 (No NPK) and the lowest (18.60) was found from F_2 treatment.

4.7.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and NPKS fertilizer had significant effect on unfilled grains panicle^{-1} of rice (Appendix V and Table 6). The maximum (26.90) unfilled grains panicle^{-1} was observed from V_1F_0 and it was statistically similar with V_0F_0 (26.77) and the minimum (15.60) was observed from V_1F_3 which was statistically at par with V_3F_3 (16.83), V_2F_3 (17.30) and V_3F_2 (17.63) treatments. This might be due to the nitrogenous fertilizer which increases vegetative growth resulting decrease the number of filled grains.

Table 6. Interaction effect of vermicompost and NPKS fertilizer on panicle length, number of filled grain panicle^{-1}, unfilled grains panicle^{-1} and 1000-grain weight of rice

Vermicompost × NPKS fertilizer	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)
V_0F_0	19.86 i	102.7 g	26.77 a	19.70 e
V_0F_1	21.15 f-h	147.7 ef	21.57 c-e	21.67 b-d
V_0F_2	21.54 fg	161.0 c-f	20.27 d-f	22.63 a-d
V_0F_3	23.34 e	188.0 a-d	19.13 fg	23.57 a
V_1F_0	20.49 hi	142.9 f	26.90 a	21.00 de
V_1F_1	21.03 gh	146.1 ef	23.27 bc	22.17 a-d
V_1F_2	22.08 f	178.8 a-e	17.93 gh	22.87 a-c
V_1F_3	23.88 de	195.7 ab	15.60 i	23.03 a-c
V_2F_0	21.89 fg	133.9 fg	24.20 b	22.03 a-d
V_2F_1	23.45 e	162.0 b-f	21.73 cd	22.60 a-d
V_2F_2	24.17 c-e	178.9 a-e	19.37 e-g	22.20 a-c
V_2F_3	24.95 c	194.4 a-c	17.30 g-i	22.50 a-d
V_3F_0	24.67 cd	158.6 d-f	22.57 bc	21.40 c-e
V_3F_1	25.06 bc	184.9 a-d	18.93 f-h	23.00 a-c
V_3F_2	27.30 a	200.4 a	17.63 g-i	23.83 a
V_3F_3	25.91 b	196.8 a	16.83 hi	23.30 ab
$LSD_{(0.05)}$	0.9374	34.03	2.217	1.843
CV (%)	2.43	12.12	6.45	4.95

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.8 Weight of 1000-grain

4.8.1 Effect of vermicompost

Different levels of vermicompost had significant effect on 1000-grain weight of rice (Appendix V and Table 4). The highest 1000-grain weight was calculated from V_3 (22.88 g) which was statistically identical to V_2 (22.33 g) and V_1 (22.27 g) whereas, the lowest (21.89 g) was found from V_0 which was statistically similar with V_1 (22.27 g) and V_2 (22.33 g) treatment.

4.8.2 Effect of NPKS fertilizer

1000-grain weight of rice significantly influenced by different levels of NPKS fertilizers (Appendix V and Table 5). The highest 1000-grain weight was calculated from F_3 (23.23 g) which was statistically similar with F_2 (22.75 g) and F_1 (22.36 g) whereas, the lowest (21.03 g) was found from F_0 treatment.

4.8.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on 1000-grain weight of rice (Appendix V and Table 6). The highest 1000-grain weight (23.83 g) was obtained from V_3F_2 which was statistically similar with V_0F_3 (23.57 g), V_3F_3 (23.30 g), V_1F_3 (23.03 g), V_3F_1 (23.00 g), V_1F_2 (22.87 g), V_2F_1 (22.60 g), V_2F_3 (22.50 g), V_2F_2 (22.20 g), V_1F_1 (22.17 g) and V_2F_0 (22.03 g) whereas, the lowest (19.70 g) was recorded from V_0F_0 and it was statistically similar with V_1F_0 (21.00 g) and V_3F_0 (21.40 g) treatment. Yang *et al.* (2004) recorded that 1000-grain weight was increased by the application of chemical fertilizer along with organic manure. The increase in grain yield components can be due to the fact that available water enhanced nutrient availability which improved nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to sink (Ebaid and El-Refaee, 2007). Similar results were found by Hoque (1999) and Apostol (1989).

4.9 Grain yield

4.9.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on grain yield of rice (Appendix V and Table 7). The highest grain yield (6.99 t ha^{-1}) was obtained from V_3 and the lowest (5.76 t ha^{-1}) was observed from V_0 (control) treatment. Datta and Banik (1994) noticed the higher grain yields (4.28 t ha^{-1}) of rice were obtained with the application of poultry manure @ 5 t ha^{-1} compared to other treatments involving organics.

4.9.2 Effect of NPKS fertilizer

Significant variation was observed on the grain yield of rice at different doses of NPKS fertilizer (Appendix V and Table 8). The maximum grain yield (7.16 t ha^{-1}) was found from F_3 and the lowest (5.14 t ha^{-1}) was observed from F_0 (control) treatment where no fertilizer was applied. Higher yields of rice have been realized without over depleting the soil fertility when fertilizers were applied based on soil test values (Prasad and Prasad, 1994).

4.9.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and NPKS fertilizer had significant effect on grain yield of rice (Appendix V and Table 9). The highest grain yield (7.89 t ha^{-1}) was observed from V_3F_2 and the lowest (4.41 t ha^{-1}) was observed from V_0F_0 and it was statistically similar with V_0F_1 (4.92 t ha^{-1}) treatment. The yield advantages due to integration of organic sources and inorganic fertilizers over chemical fertilizers alone might be due to the availability of nutrients for a shorter period as mineralization of nitrogen is more rapid and in turn the losses of inorganic nitrogen due to volatilization, de-nitrification and leaching etc., would be more. The results are in conformity with Prabhakara Setty *et al.* (2007) and Subbalakshmi (2007). Salem (2006) reported that application of FYM along with nitrogen fertilizer significantly increased the grain yield in rice. This is also in agreement with the findings of Rani *et al.* (2001) and Haque *et al.* (2001).

Table 7. Effect of vermicompost on grain yield, straw yield, biological yield and harvest index of rice

Vermicompost	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_0	5.76 c	6.12 d	11.88 d	48.24 a
V_1	6.33 b	7.04 c	13.37 c	47.19 ab
V_2	6.56 b	7.51 b	14.07 b	46.58 b
V_3	6.99 a	8.04 a	15.02 a	46.36 b
$LSD_{(0.05)}$	0.291	0.318	0.44	1.65
CV (%)	5.44	5.32	3.88	4.20

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.10 Straw yield

4.10.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on straw yield of rice (Appendix V and Table 7). The maximum straw yield (8.04 t ha^{-1}) was obtained from V_3 and the minimum (6.12 t ha^{-1}) was found from V_0 (control) treatment. Incorporation of organic manure (FYM @ 5 t ha^{-1}) with recommended dose of fertilizers produced significantly higher straw yield in rice crop (Rabeya Khanam *et al.*, 1997). Maximum straw yield was obtained by *Budhar et al.* (1991) with the application of poultry manure @5 tha^{-1} and it was found superior to FYM @ 5 t ha^{-1}.

4.10.2 Effect of NPKS fertilizer

Significant variation was observed on straw yield of rice at different doses of NPKS fertilizer (Appendix V and Table 8). The highest (8.11 t ha^{-1}) straw yield was observed from F_3 (High NPKS) and the lowest (6.48 t ha^{-1}) was found from F_0 (control) treatment and it was statistically similar with F_1 (6.72 t ha^{-1}) treatment. Blaise and Rajendra Prasad (1996) observed a significant increase in straw yield of rice up to 60 kg N ha^{-1}.

4.10.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and NPKS fertilizer had significant effect on straw yield of rice (Appendix V and Table 9). The highest straw yield (8.73 t ha^{-1}) was obtained from V_3F_2 and it was statistically similar with V_3F_3 (8.54 t ha^{-1}) and V_2F_3 (8.35 t ha^{-1}) whereas, the lowest (5.42 t ha^{-1}) was recorded from V_0F_0 which was statistically at par with V_1F_0 (5.50 t ha^{-1}) treatment. Rahman *et al.* (2009) reported that the application of organic manure and chemical fertilizers increased the straw yields of rice. These findings are corroborated with the work of Mannan *et al.* (2000), Khan (1998), Islam (1997), Ahmed and Rahman (1991). Organic manure in combination with inorganic fertilizers might be increased the vegetative growth of plants and thereby increased straw yield of rice.

Table 8. Effect of NPKS fertilizer on grain yield, straw yield, biological yield and harvest index of rice

NPKS fertilizer	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_0	5.14 d	6.48 c	11.62 d	44.15 c
F_1	6.48 c	6.72 c	13.20 c	49.14 a
F_2	6.86 b	7.39 b	14.25 b	48.22 ab
F_3	7.16 a	8.11 a	15.27 a	46.86 b
$LSD_{(0.05)}$	0.291	0.318	0.44	1.65
CV (%)	5.44	5.32	3.88	4.20

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.11 Biological yield

4.11.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on biological yield of rice (Appendix V and Table 7). The highest biological yield (15.02 t ha^{-1}) was obtained from V_3 and the lowest (11.88 t ha^{-1}) was observed from V_0 (control) treatment.

4.11.2 Effect of NPKS fertilizer

Significant variation was observed on the biological yield of rice at different doses of NPKS fertilizer (Appendix V and Table 8). The highest biological yield (15.27 t ha^{-1}) was found from F_3 (High NPKS) and the lowest (11.62 t ha^{-1}) was obtained from F_0 (control) treatment where no fertilizer was applied.

4.11.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and NPKS fertilizer had significant effect on biological yield of rice (Appendix V and Table 9). The highest biological yield (16.62 t ha^{-1}) was obtained from V_3F_2 and the lowest (9.91 t ha^{-1}) was observed from V_0F_0 which was statistically similar with V_1F_0 (10.72 t ha^{-1}) treatment. Higher biological yield might be due to the increase in growth and yield attributes (Ebaid and El-Refaee, 2007). Organic matter provided the micro nutrients and increased the cation exchange capacity of soil thus improved nutrients availability which in combinations with inorganic fertilizers enhanced the growth and yield (Rani *et al.* 2001).

4.12 Harvest index

4.12.1 Effect of vermicompost

Significant variation was observed on the harvest index of rice when the field was incorporated with different doses of vermicompost (Appendix V and Table 7). The highest harvest index (48.24 %) was obtained from V_0 which was statistically similar (47.19 %) with V_1 whereas, the lowest (46.36 %) was observed from V_3 which was statistically similar (46.58 %) with V_2 treatment. Radha Madhav (1995) stated that relatively higher harvest index was obtained with application of FYM @ 120 kg N ha^{-1}.

4.12.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on the harvest index of rice (Appendix V and Table 8). The highest harvest index (49.14 %) was observed from F_1 which was statistically similar (48.22 %) with F_2 whereas, the lowest (44.15 %) was obtained from F_0 (control) treatment, where no fertilizer was applied.

4.12.3 Interaction effect of vermicompost and NPKS fertilizer

Combined application of different doses of vermicompost and NPKS fertilizer had significant effect on harvest index of rice (Appendix V and Table 9). The highest harvest index (50.64 %) was found from V_2F_0 and it was statistically similar with V_1F_1 (50.29 %), V_1F_0 (49.47 %), V_1F_2 (49.26 %), V_2F_1 (48.91 %), V_3F_0 (48.49 %), V_1F_3 (47.55 %) and V_2F_2 (47.42 %) whereas, the lowest (43.35 %) was observed from V_0F_1, which was statistically similar with V_0F_2 (44.20 %), V_0F_0 (44.52 %), V_0F_3 (44.82 %), V_2F_3 (45.92 %), V_3F_1 (46.30 %) and V_3F_2 (47.47 %) treatment. Higher yield and harvest index due to poultry manure and recommended fertilizer indicates better partitioning of photosynthetic substance to economic yield. Appreciably high harvest index shows the efficiency of converting biological yield into economic yield (Kusalkar *et al.*, 2003).

Table 9. Interaction effect of vermicompost and NPKS fertilizer on grain yield, straw yield, biological yield and harvest index of rice

Vermicompost × NPKS fertilizer	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_0F_0	4.41 e	5.42 j	9.91 j	44.52 f-h
V_0F_1	4.92 de	6.43 i	11.35 hi	43.35 h
V_0F_2	5.30 d	6.69 g-i	11.99 h	44.20 gh
V_0F_3	5.93 c	7.30 e-g	13.23 fg	44.82 f-h
V_1F_0	5.30 d	5.50 j	10.72 ij	49.47 a-c
V_1F_1	6.70 b	6.63 hi	13.33 fg	50.29ab
V_1F_2	6.89 b	7.09 f-h	13.98 d-f	49.26 a-c
V_1F_3	7.03 b	7.75 c-e	14.79 b-d	47.55 a-f
V_2F_0	6.59 b	6.42 i	13.02 g	50.64 a
V_2F_1	6.79 b	7.09 f-h	13.89 e-g	48.91a-d
V_2F_2	6.94 b	7.69 d-f	14.64 c-e	47.42 a-f
V_2F_3	7.09 b	8.35 a-c	15.44 bc	45.92 d-h
V_3F_0	6.73 b	7.15 e-h	13.88 e-g	48.49 a-e
V_3F_1	6.91 b	8.02 b-d	14.93 bc	46.30 c-h
V_3F_2	7.89 a	8.73 a	16.62 a	47.47 e-h
V_3F_3	7.12 b	8.54 ab	15.66 b	45.49 b-g
$LSD_{(0.05)}$	0.582	0.635	0.879	3.3
CV (%)	5.44	5.32	3.88	4.20

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.13 Nutrient concentrations in grain

4.13.1 Nitrogen content

4.13.1.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on nitrogen content in grain of rice (Appendix VI and Table 10). The maximum nitrogen content in grain (0.97 %) was obtained from V_3 and the minimum (0.49 %) was observed from V_0 (control) treatment. It was observed that nitrogen content in rice plant increased due to higher rate of application of vermicompost. Jat and Ahlawat (2004) reported that application of vermicompost to chickpea improved N and P uptake by crop over no vermicompost treatment.

4.13.1.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on nitrogen content in grain of rice (Appendix VI and Table 11). The maximum nitrogen content in grain (1.04 %) was obtained from F_3 and the minimum (0.58 %) was observed from F_0 (control) treatment.

4.13.1.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on nitrogen content in grain of BRRI dhan29 (Appendix VI and Table 12). The maximum nitrogen content in grain (1.192 %) was obtained from V_3F_3 which was statistically similar with V_2F_3 (1.153 %) and V_1F_3 (1.104 %) whereas, the minimum (0.334 %) was observed from V_0F_0 (control) treatment. Sengar *et al.* (2000) reported that the N uptake by rice grain increased significantly with the combined application of organic manure and chemical fertilizers. Rahman (2001); Duhan and Singh (2002); Azim (1999) and Hoque (1999) also reported similar results.

Table 10. Effect of vermicompost on NPKS concentration in rice grain

Vermicompost	Concentration (%) in grain			
	N	P	K	S
V_0	0.49 c	0.17 c	0.34 c	0.14 c
V_1	0.81 b	0.22 b	0.39 b	0.16 bc
V_2	0.84 b	0.24 b	0.43 a	0.17 b
V_3	0.97 a	0.27 a	0.33 c	0.20 a
$LSD_{(0.05)}$	0.053	0.026	0.026	0.026
CV (%)	8.32	6.60	8.39	5.77

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.13.2 Phosphorus content

4.13.2.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on phosphorus content in grain of rice (Appendix VI and Table 10). The maximum phosphorus content in grain (0.27 %) was found from V_3 and the minimum (0.17 %) was observed from V_0 (control) treatment.

4.13.2.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on phosphorus content in grain of rice (Appendix VI and Table 11). The maximum phosphorus content in grain (0.24 %) was observed from F_3 which was statistically similar with F_2 (0.23 %) and F_1 (0.22 %) whereas, the minimum (0.21 %) was observed from F_0 (control) treatment and it was statistically identical to F_1 (0.22 %) and F_2 (0.23 %).

4.13.2.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on phosphorus content in grain of BRRI dhan29 (Appendix VI and Table 12). The maximum phosphorus content in grain (0.287 %) was observed from V_3F_3 which was statistically similar with V_3F_2 (0.272 %), V_2F_3 (0.268 %), V_2F_3 (0.258 %), V_3F_0 (0.253 %), V_2F_2 (0.247 %) and V_2F_1 (0.240 %) whereas, the minimum (0.149 %) was found from V_0F_0 (control) treatment which was statistically at par with V_0F_1 (0.163 %), V_0F_2 (0.171 %) and V_0F_3 (0.181 %). Sengar *et al.* (2000) recorded that the highest P uptake by rice grain was recorded with the combined application of organic manure and phosphatic fertilizers.

4.13.3 Potassium content

4.13.3.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on potassium content in grain of rice (Appendix VI and Table 10). The maximum potassium content in grain (0.43 %) was obtained from V_2 and the minimum (0.33 %) was observed from V_3 and it was statistically similar with V_0 (0.34 %) treatment.

4.13.3.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on potassium content in grain of rice (Appendix VI and Table 11). The maximum potassium content in grain (0.39 %) was found from F_3 which was statistically identical with F_2 (0.37 %) and F_1 (0.37 %) whereas, the minimum (0.34 %) was observed from F_0 (control) treatment.

4.13.3.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on potassium content in grain of BRRI dhan29 (Appendix VI and Table 12).The maximum potassium content in grain (0.474 %) was found from V_2F_3 which was statistically similar with V_2F_1 (0.453 %) and V_2F_2 (0.445 %) whereas, the minimum (0.295 %) was observed from V_0F_0 which was statistically similar with V_3F_1 (0.327 %), V_3F_2 (0.329 %), V_2F_0 (0.332 %), V_0F_1 (0.336 %), V_3F_0 (0.340 %), V_0F_2 (0.344 %), V_0F_3 (0.345 %) and V_3F_3 (0.345 %). Kudu *et al.* (1991) obtained highest potassium content in rice grain due to the application of highest doses of NPK with the association of farmyard manure. Singh *et al.* (2001) revealed that potassium content in grains was increased due to combined application of organic manure and chemical fertilizers. Similar results also found by Verma *et al.* (1991).

Table 11. Effect of NPKS fertilizer on NPKS concentration in rice grain

NPKS fertilizer	Concentration (%) in grain			
	N	P	K	S
F_0	0.58 c	0.21 b	0.34 b	0.14 c
F_1	0.73 b	0.22 ab	0.37 a	0.16 bc
F_2	0.76 b	0.23 ab	0.37 a	0.18 ab
F_3	1.04 a	0.24 a	0.39 a	0.19 a
$LSD_{(0.05)}$	0.053	0.026	0.026	0.026
CV (%)	8.32	6.60	8.39	5.77

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.13.4 Sulphur content

4.13.4.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on sulphur content in grain of rice (Appendix VI and Table 10). The maximum sulphur content in grain (0.20 %) was observed from V_3 and the minimum (0.14 %) was observed from V_0 which was statistically similar with V_1 (0.16 %) treatment.

4.13.4.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on sulphur content in grain of rice (Appendix VI and Table 11). The maximum sulphur content in grain (0.19 %) was obtained from F_3 and it was statistically similar with F_2 (0.18 %) whereas, the minimum (0.14 %) was observed from F_0 which was statistically similar with F_1 (0.16 %) treatment.

4.13.4.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on sulphur content in grain of BRRI dhan29 (Appendix VI and Table 12). The maximum sulphur content in grain (0.217 %) was obtained from V_3F_3 which was statistically similar with V_3F_2 (0.205 %), V_2F_3 (0.204 %), V_3F_1 (0.196 %), V_1F_3 (0.192 %), V_1F_2 (0.188 %), V_3F_0 (0.181 %) and V_2F_2 (0.179 %) whereas, the minimum (0.104 %) was observed from V_0F_0 (control) treatment which was statistically similar with V_1F_0 (0.121 %), V_0F_1 (0.128 %), V_2F_0 (0.134 %), V_0F_2 (0.135 %) and V_1F_1 (0.154 %) treatments. Sengar *et al.* (2000) recorded the higher uptake of S with the application of manure and fertilizers either alone or in combinations. Similar results were also reported by Rahman (2001).

Table 12. Interaction effect of NPKS fertilizer on NPKS concentration in rice grain

Vermicompost × NPKS fertilizer	Concentration (%) in grain			
	N	P	K	S
V_0F_0	0.334 g	0.149 h	0.295 f	0.104 f
V_0F_1	0.441 f	0.163 gh	0.336 ef	0.128 d-f
V_0F_2	0.529 ef	0.171 f-h	0.344 ef	0.135 c-f
V_0F_3	0.724 c	0.181 e-h	0.345 ef	0.158 b-e
V_1F_0	0.565 de	0.207 d-g	0.364 de	0.121 ef
V_1F_1	0.872 b	0.215 c-g	0.375 de	0.154 b-f
V_1F_2	0.705 c	0.223 b-f	0.399 cd	0.188 ab
V_1F_3	1.104 a	0.230 b-e	0.409 b-d	0.192 ab
V_2F_0	0.657 cd	0.214 d-g	0.332 ef	0.134 c-f
V_2F_1	0.704 c	0.240 a-d	0.453 ab	0.163 b-e
V_2F_2	0.851 b	0.247 a-d	0.445 a-c	0.179 a-d
V_2F_3	1.153 a	0.258 a-d	0.474 a	0.204 ab
V_3F_0	0.840 b	0.253 a-d	0.340 ef	0.181 a-c
V_3F_1	0.884 b	0.268 a-c	0.327 ef	0.196 ab
V_3F_2	0.945 b	0.272 ab	0.329 ef	0.205 ab
V_3F_3	1.192 a	0.287 a	0.345 ef	0.217 a
$LSD_{(0.05)}$	0.106	0.053	0.053	0.053
CV (%)	8.32	6.60	8.39	5.77

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.14 Nutrient concentrations in rice straw

4.14.1 Nitrogen content

4.14.1.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on nitrogen content in straw of BRRI dhan29 (Appendix VI and Table 13). The maximum nitrogen content in straw (0.76 %) was obtained from V_3 and the minimum (0.31 %) was observed from V_0 (control) treatment. Baron *et al.* (1995) found that the addition of organic manure has a positive influence on the N uptake by wheat plants.

4.14.1.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on nitrogen content in straw of BRRI dhan29 (Appendix VI and Table 14). The maximum nitrogen content in straw (0.83 %) was obtained from F_3 and the minimum (0.40 %) was observed from F_0 (control) treatment. Jeong *et al.* (1996) found that 5 t/ha fermented chicken manure increased nitrogen concentration in rice plant.

4.14.1.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on nitrogen content in straw of BRRI dhan29 (Appendix VI and Table 15). The maximum nitrogen content in straw (0.98 %) was obtained from V_3F_3 which was statistically similar with V_2F_3 (0.95 %) and the minimum (0.14 %) was observed from V_0F_0 (control) treatment.

Table 13. Effect of vermicompost on NPKS concentration in straw of Boro rice

Vermicompost	Concentration (%) in straw			
	N	P	K	S
V_0	0.31 c	0.13 b	1.50 c	0.09 b
V_1	0.60 b	0.15 ab	1.58 b	0.11 ab
V_2	0.64 b	0.16 a	1.63 a	0.12 a
V_3	0.76 a	0.17 a	1.65 a	0.12 a
$LSD_{(0.05)}$	0.046	0.026	0.046	0.026
CV (%)	9.35	8.24	3.58	8.36

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.14.2 Phosphorus content

4.14.2.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on phosphorus content in straw of BRRI dhan29 (Appendix VI and Table 13). The maximum phosphorus content in straw (0.17 %) was found from V_3 which was statistically similar with V_2 (0.16 %) and V_1 (0.15 %) whereas, the minimum (0.13 %) was observed from V_0 (control) treatment and it was statistically similar with V_1 (0.15 %) treatment.

4.14.2.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on phosphorus content in straw of BRRI dhan29 (Appendix VI and Table 14). The maximum phosphorus content in straw (0.18 %) was observed from F_3 which was statistically similar with F_2 (0.16 %) and the minimum (0.13 %) was observed from F_0 (control) treatment which was statistically similar with F_1 (0.14 %).

4.14.2.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on phosphorus content in straw of BRRI dhan29 (Appendix VI and Table 15). The maximum phosphorus content in straw (0.19 %) was observed from V_3F_3 which was statistically similar with V_3F_2 (0.18 %), V_2F_3 (0.18 %), V_2F_2 (0.17 %), V_1F_3 (0.17 %), V_0F_3 (0.17 %), V_3F_1 (0.16 %), V_1F_2 (0.16 %), V_2F_1 (0.15 %), V_3F_0 (0.14 %), V_2F_0 (0.14 %), V_1F_1 (0.14 %), V_0F_2 (0.14 %) and V_1F_0 (0.13 %) whereas, the minimum (0.10 %) was observed from V_0F_0 (control) treatment which was statistically similar with V_0F_1 (0.13 %), V_1F_0 (0.13 %), V_0F_2 (0.14 %), V_1F_1 (0.14 %), V_2F_0 (0.14 %), V_3F_0 (0.14 %), V_2F_1 (0.15 %). A significant increase in P content in rice straw due to the application of organic manure and fertilizers has been reported by investigators (Azim, 1999 and Hoque, 1999).

4.14.3 Potassium content

4.14.3.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on potassium content in straw of BRRI dhan29 (Appendix VI and Table 13). The maximum potassium content in straw (1.65 %) was obtained from V_3 and it was statistically similar with V_2 (1.63 %) treatment whereas, the minimum (1.50 %) was observed from V_0 treatment.

4.14.3.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on potassium content in straw of BRRI dhan29 (Appendix VI and Table 14). The maximum potassium content in straw (1.81 %) was found from F_3 and the minimum (1.32 %) was observed from F_0 (control) treatment.

4.14.3.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on potassium content in straw of BRRI dhan29 (Appendix VI and Table 15). The maximum potassium content in straw (1.88 %) was found from V_3F_3 which was statistically similar with V_3F_2 (1.81 %) and V_1F_3 (1.84 %) whereas, the minimum (1.26 %) was observed from V_0F_0 (control) treatment.

Table 14. Effect of NPKS fertilizer on NPKS concentration in straw of Boro rice

NPKS fertilizer	Concentration (%) in straw			
	N	P	K	S
F_0	0.40 d	0.13 c	1.32 d	0.09 c
F_1	0.48 c	0.14 bc	1.54 c	0.10 bc
F_2	0.60 b	0.16 ab	1.70 b	0.12 ab
F_3	0.83 a	0.18 a	1.81 a	0.13 a
$LSD_{(0.05)}$	0.046	0.026	0.046	0.026
CV (%)	9.35	8.24	3.58	8.36

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.14.4 Sulphur content

4.14.4.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on sulphur content in straw of BRRI dhan29 (Appendix VI and Table 13). The maximum sulphur content in straw (0.12 %) was observed from V_3 and V_2 which were statistically similar with V_1 (0.11 %) whereas, the minimum (0.09 %) was observed from V_0 (control) treatment and it was statistically similar with V_1 (0.11 %) treatment.

4.14.4.2 Effect of NPKS fertilizer

Different doses of NPKS fertilizer showed significant variation on sulphur content in straw of BRRI dhan29 (Appendix VI and Table 14). The maximum sulphur content in straw (0.13 %) was obtained from F_3 and it was statistically similar with F_2 (0.12 %) whereas, the minimum (0.09 %) was observed from F_0 which was statistically similar with F_1 (0.10 %) treatment.

4.14.4.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on sulphur content in straw of BRRI dhan29 (Appendix VI and Table 15). The maximum sulphur content in straw (0.14 %) was obtained from V_3F_3 which was statistically similar with V_3F_2 (0.13 %), V_2F_3 (0.13 %), V_2F_2 (0.13 %), V_1F_3 (0.13 %), V_0F_3 (0.13 %), V_3F_1 (0.12 %), V_1F_2 (0.12 %), V_2F_1 (0.11 %), V_3F_0 (0.10 %), V_2F_0 (0.10 %), V_1F_1 (0.10 %), V_0F_2 (0.09 %) and V_1F_0 (0.09 %) whereas, the minimum (0.05 %) was observed from V_0F_0 (control) treatment which was statistically similar with V_0F_1 (0.08 %), V_1F_0 (0.09 %), V_0F_2 (0.10 %), V_1F_1 (0.10 %), V_2F_0 (0.10 %), V_3F_0 (0.10 %), V_2F_1 (0.10 %).

Table 15. Interaction effect of NPKS fertilizer on NPKS concentration in straw of Boro rice

Vermicompost × NPKS fertilizer	Concentration (%) in straw			
	N	P	K	S
V_0F_0	0.14 h	0.10 c	1.26 h	0.070 c
V_0F_1	0.24 g	0.13 bc	1.39 g	0.08 bc
V_0F_2	0.33 fg	0.14 a-c	1.58 f	0.09 a-c
V_0F_3	0.52 e	0.17 ab	1.76 b-d	0.13 ab
V_1F_0	0.37 f	0.13 a-c	1.30 h	0.09 a-c
V_1F_1	0.51 e	0.14 a-c	1.47 g	0.10 a-c
V_1F_2	0.67 cd	0.16 ab	1.71 de	0.12 ab
V_1F_3	0.87 b	0.17 ab	1.84 ab	0.13 ab
V_2F_0	0.46 e	0.14 a-c	1.47 g	0.10 a-c
V_2F_1	0.50 e	0.15 a-c	1.63 ef	0.10 a-c
V_2F_2	0.65 d	0.17 ab	1.68 de	0.13 ab
V_2F_3	0.95 ab	0.18 ab	1.74 cd	0.13 ab
V_3F_0	0.64 d	0.14 a-c	1.25 h	0.10 a-c
V_3F_1	0.67 cd	0.16 ab	1.68 de	0.12 ab
V_3F_2	0.76 c	0.18 ab	1.81 a-c	0.13 ab
V_3F_3	0.98 a	0.19 a	1.88 a	0.14 a
$LSD_{(0.05)}$	0.091	0.055	0.091	0.051
CV (%)	9.35	8.24	3.58	8.36

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.15 Nutrient status in post harvest soil

4.15.1 Organic matter (%)

4.15.1.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on organic matter content in postharvest soil of research farm (Appendix VII and Table 16). The maximum organic matter in postharvest soil (1.66 %) was obtained from V_3 and the minimum (1.24 %) was observed from V_0 (control) treatment. Vermicompost added organic matter in the soil as consequence the amount of organic matter in post harvest soil showed higher values compared to control plot.

4.15.1.2 Effect of NPKS fertilizer

Different levels of fertilizer showed significant variation on organic matter content in postharvest soil of research farm (Appendix VII and Table 17). The maximum organic matter in postharvest soil (1.51 %) was obtained from F_2 which was statistically similar with F_1 (1.49 %) and the minimum (1.29 %) was found from F_0 (control) treatment.

4.15.1.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on organic matter content in postharvest soil of research farm (Appendix VII and Table 18). The maximum organic matter content in postharvest soil (1.77 %) was obtained from V_3F_1 which was statistically similar with V_3F_2 (1.77 %) and the minimum (1.07 %) was observed from V_0F_0 (control) treatment. Xu *et al.* (2008) reported that application of chemical fertilizer with organic manure increase soil organic matter.

4.15.2 Total N (%)

4.15.2.1 Effect of vermicompost

Content of total N in postharvest soil due to addition of vermicompost was not significant (Appendix VII and Table 16). However a slight higher total nitrogen content in postharvest soil (0.079 %) was found from V_3 and the minimum (0.061 %) was observed from V_0 (control) treatment. This was due to the fact that vermicompost added N in soil and reduced the loss of nitrogen in soil. Bangar *et al*. (1990) found that compost enriched the N content of soil.

4.15.2.2 Effect of NPKS fertilizer

Different levels of fertilizer showed non-significant effect on total nitrogen content in postharvest soil of research farm (Appendix VII and Table 17). Numerically the maximum total nitrogen content in postharvest soil (0.079 %) was found from F_3 and the minimum (0.062 %) was observed from F_0 (control) treatment.

4.15.2.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had non-significant effect on total nitrogen content in postharvest soil of research farm (Appendix VII and Table 18). Numerically the maximum total nitrogen content in postharvest soil (0.087 %) was found from V_3F_3 and the minimum (0.052 %) was observed in V_0F_0 (control) treatment. Tolanur and Badanur (2003) reported that soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with chemical fertilizer.

Table 16. Effect of vermicompost on organic matter and NPKS content in post harvest soil

Vermicompost	Organic matter (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (mg kg^{-1})	Available S (mg kg^{-1})
V_0	1.24 d	0.061	13.58 c	13.10 d	10.82 d
V_1	1.37 c	0.068	13.80 c	14.65 c	12.16 c
V_2	1.46 b	0.073	15.47 b	16.29 b	12.45 b
V_3	1.66 a	0.079	16.17 a	18.05 a	13.19 a
$LSD_{(0.05)}$	0.026	NS	0.328	0.351	0.204
CV (%)	1.67	10.73	2.67	2.71	2.02

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.15.3 Available P (mg kg^{-1})

4.15.3.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on available phosphorus in postharvest soil of research farm (Appendix VII and Table 16). The maximum available phosphorus content in postharvest soil (16.17 mg kg^{-1}) was obtained from V_3 and the minimum (13.58 mg kg^{-1}) was observed from V_0 and it was statistically similar with V_1 (13.80 mg kg^{-1}) treatment.

4.15.3.2 Effect of NPKS fertilizer

Different levels of fertilizer showed significant variation on available phosphorus content in postharvest soil of research farm (Appendix VII and Table 17). The maximum available phosphorus content in postharvest soil (15.80 mg kg^{-1}) was obtained from F_3 and the minimum (13.74 mg kg^{-1}) was observed from F_0.

4.15.3.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on available phosphorus content in postharvest soil of research farm (Appendix VII and Table 18). The maximum available phosphorus content in postharvest soil (17.14 mg kg^{-1}) was obtained from V_3F_3 which was statistically similar with V_3F_2 (16.67 mg kg^{-1}) and the minimum (12.52 mg kg^{-1}) was observed from V_1F_0 which was statistically similar with V_0F_0 (12.85 mg kg^{-1}) and V_0F_1 (13.09 mg kg^{-1}).

Table 17. Effect of NPKS fertilizer on organic matter and NPKS content in post harvest soil

NPKS Fertilizer	Organic matter (%)	Total N (%)	Available P ($mg\ kg^{-1}$)	Exchangeable K ($mg\ kg^{-1}$)	Available S ($mg\ kg^{-1}$)
F_0	1.29 c	0.062	13.74 d	13.27 d	11.61 d
F_1	1.49 a	0.067	14.43 c	14.90 c	11.98 c
F_2	1.51 a	0.073	15.06 b	16.22 b	12.19 b
F_3	1.43 b	0.079	15.80 a	17.70 a	12.85 a
$LSD_{(0.05)}$	0.026	NS	0.328	0.351	0.204
CV (%)	1.67	10.73	2.67	2.71	2.02

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.15.4 Exchangeable K ($mg\ kg^{-1}$)

4.15.4.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on exchangeable potassium in postharvest soil of research farm (Appendix VII and Table 16). The maximum exchangeable potassium in postharvest soil (18.05 $mg\ kg^{-1}$) was observed from V_3 and the minimum (13.10 $mg\ kg^{-1}$) was observed from V_0. Increase in exchangeable K due to the application of organic manure might be attributed to the release of K to the available pool of the soil besides the reduction of K fixation. These results are similar with the findings of some earlier workers (Saleque *et al.,* 1991; Bhardwaj and Omanwar, 1994).

4.15.4.2 Effect of NPKS fertilizer

Different levels of fertilizer showed significant variation on exchangeable potassium in postharvest soil of research farm (Appendix VII and Table 17). The maximum exchangeable potassium in postharvest soil (17.70 $mg\ kg^{-1}$) was observed from F_3 and the minimum (13.27 $mg\ kg^{-1}$) was observed from F_0.

4.15.4.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on exchangeable potassium in postharvest soil of research farm (Appendix VII and Table 18). The maximum exchangeable potassium in postharvest soil (20.21 mg kg^{-1}) was observed from V_3F_3 and the minimum (11.60 mg kg^{-1}) was observed from V_0F_0.

4.15.5 Available S (mg kg^{-1})

4.15.5.1 Effect of vermicompost

Different doses of vermicompost showed significant variation on available sulphur content in postharvest soil of research farm (Appendix VII and Table 16). The maximum available sulphur content in postharvest soil (13.19 mg kg^{-1}) was obtained from V_3 and the minimum (10.82 mg kg^{-1}) was observed from V_0.

4.15.5.2 Effect of NPKS fertilizer

Different levels of fertilizer showed significant variation on available sulphur content in postharvest soil of research farm (Appendix VII and Table 17). The maximum available sulphur content in postharvest soil (12.58 mg kg^{-1}) was obtained from F_3 and the minimum (11.61 mg kg^{-1}) was observed from F_0.

4.15.5.3 Interaction effect of vermicompost and NPKS fertilizer

Interaction effect of different doses of vermicompost and NPKS fertilizer had significant effect on available sulphur content in postharvest soil of research farm (Appendix VII and Table 18). The maximum available sulphur content in postharvest soil (14.08 mg kg^{-1}) was obtained from V_3F_3 and the minimum (10.39 mg kg^{-1}) was observed from V_0F_0 which was statistically similar with V_0F_1 (10.60 mg kg^{-1}).

Table 18. Interaction effect of vermicompost and NPKS fertilizer on organic matter and NPKS content in post harvest soil

Vermicompost × NPKS fertilizer	Organic matter (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (mg kg^{-1})	Available S (mg kg^{-1})
V_0F_0	1.07 j	0.052	12.85 i	11.60 i	10.39 l
V_0F_1	1.20 i	0.059	13.09 hi	12.65 h	10.60 kl
V_0F_2	1.32 gh	0.063	13.85 g	13.60 g	10.80 k
V_0F_3	1.38 ef	0.069	14.53 ef	14.55 f	11.50 j
V_1F_0	1.27 h	0.060	12.52 i	12.35 h	11.63 ij
V_1F_1	1.30 gh	0.064	13.56 gh	13.68 g	12.28 e-h
V_1F_2	1.39 ef	0.069	13.95 fg	15.85 e	12.05 gh
V_1F_3	1.52 cd	0.078	15.17 de	16.72 d	12.67 de
V_2F_0	1.35 fg	0.065	14.65 e	13.48 g	11.98 hi
V_2F_1	1.43 e	0.070	15.12 de	15.40 e	12.23 f-h
V_2F_2	1.50 cd	0.076	15.77 cd	16.96 d	12.47 d-f
V_2F_3	1.55 bc	0.080	16.35 bc	19.34 b	13.13 bc
V_3F_0	1.49 d	0.071	14.95 e	15.64 e	12.43 d-g
V_3F_1	1.77 a	0.077	15.94 c	17.86 c	12.82 cd
V_3F_2	1.76 a	0.082	16.67 ab	18.47 c	13.45 b
V_3F_3	1.603 b	0.087	17.14 a	20.21 a	14.08 a
$LSD_{(0.05)}$	0.053	NS	0.657	0.702	0.409
CV (%)	1.67	10.73	2.67	2.71	2.02

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Chapter 5
Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at Sher-e-Bangla Agricultural University Farm (SAU Farm), Dhaka 1207 (Tejgaon series under AEZ No. 28) during the *boro* season of 2013-2014 to study the effect of organic and inorganic fertilizers on growth and yield of BRRI dhan29. The soil was silty loam in texture having pH (5.7), organic matter (1.09%). Randomized completely block design was followed with sixteen treatment combinations having unit plot size of 2 m × 2 m (4 m^2) and replicated thrice. Four rates of vermicompost 0, 1, 2 and 4 t ha^{-1} (designated as V_0, V_1, V_2 and V_3) and four rates of NPKS designated as F_0 (No N, No P, No K, No S), F_1 (50, 8, 33, 6 kg ha^{-1} N, P, K, S, respectively), F_2 (100, 16, 66, 12 kg ha^{-1} N, P, K, S, respectively) and F_3 (150, 24, 99, 18 kg ha^{-1} N, P, K, S, respectively) were used. The treatments were V_0F_0= Control (No vermicompost + No NPKS), V_0F_1= (No vermicompost + Low level of NPKS), V_0F_2 = (No vermicompost + Medium level of NPKS), V_0F_3 = (No vermicompost + High level of NPKS), V_1F_0 = (1 tha^{-1} vermicompost + No NPKS), V_1F_2 = (1 t ha^{-1} vermicompost + Medium level of NPKS), V_1F_3 = (1 t ha^{-1} vermicompost + High level of NPKS), V_2F_0 = (2 t ha^{-1} vermicompost + No NPKS), V_2F_1 = (2 t ha^{-1} vermicompost + Low level of NPKS), V_2F_2 = (2 t ha^{-1} vermicompost + Medium level of NPKS), V_2F_3 = (2 t ha^{-1} vermicompost + High level of NPKS), V_3F_0 = (4 t ha^{-1} vermicompost + No NPKS), V_3F_1 = (4 t ha^{-1} vermicompost + Low level of NPKS), V_3F_2 = (4 t ha^{-1} vermicompost + Medium level of NPKS), V_3F_3 = (4 t ha^{-1} vermicompost + High level of NPKS). Nitrogen from urea, P from TSP, K from muriate of potash (MoP) and S from gypsum were used. One third of urea and full dose of TSP, MP and gypsum fertilizers and vermicompost were applied in plot as per treatment combination during the final land preparation (puddling). The rest of the urea was top dressed in two equal splits at 15 and 35 day after transplanting of seedlings. Rice seedlings cv. BRRI dhan29 were transplanted on 19thJanuary 2014 and the crop was harvested on 29th May 2014. Intercultural operations were done as and when required. The data were collected plot wise for plant height, effective tillers hill^{-1}, non-effective tillers hill^{-1}, flag leaf length, panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000-grain weight, grain yield, straw yield, biological yield and harvest index. The post-harvest soil samples were analyzed for organic matter, N, P, K, and S contents. Data were analyzed using MSTAT package. The mean differences among the treatments were compared by LSD at 5% level of significance.

The highest plant height, panicle length, flag leaf length, effective tillers hill^{-1}, filled grains panicle^{-1} and 1000-grain weight of 95.78 cm, 27.30 cm, 27.27 cm, 15.30 (no.), 200.4 (no.) and 23.83 g, respectively were recorded with the application of 4 t ha^{-1} vermicompost combined with medium dose of NPKS fertilizers (V_3F_2). The lowest plant height, panicle length, flag leaf length, effective tillers hill^{-1}, filled grains panicle^{-1} and 1000-grain weight of 86.04 cm, 19.86 cm, 21.51 cm, 10.50 (no.), 102.7 (no.) and 19.70 g, respectively were obtained in the treatment that received no vermicompost and fertilizers (V_0F_0).

Grain, straw and biological yields of rice responded significantly to the application vermicompost and NPKS fertilizers. The highest grain 7.89 t ha^{-1}, straw 8.73 t ha^{-1} and biological yields 16.62 t ha^{-1} were obtained with V_3F_2 (4 t ha^{-1} vermicompost + Medium level of NPKS) treatment. The lowest grain 4.41 t ha^{-1}, straw 5.42 t ha^{-1} and biological yields 9.91 t ha^{-1} were recorded with V_0F_0, Where neither vermicompost nor fertilizers were applied.

The highest 26.90 and the lowest 15.60 number of unfilled grains panicle^{-1} were obtained with V_1F_0 and V_1F_3 treatments respectively. The highest 50.64 (%) and the lowest 43.35 (%) harvest index was obtained with V_2F_0 and V_0F_1 treatments respectively. The highest 2.88 and the lowest 0.93 number of non-effective tillers hill^{-1} were obtained with V_0F_0 and V_3F_2 treatments respectively.

Integrated use of vermicompost and NPKS fertilizers from chemical source improved plant growth and rice yield. So, 4 t ha^{-1} vermicompost and 100, 16, 66, 12 kg ha^{-1} NPKS fertilizers may recommended for cultivation of BRRI dhan29 at Sher-e-Bangla Agricultural University farm and similar environment elsewhere in Bangladesh.

The N, P, K and S contents of grain and straw influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, P, K and S contents in grain and straw (1.192, 0.14 %), (0.287, 0.10 %), (1.26 % in straw) and (0.217, 0.070 %) after harvest, respectively were recorded in V_3F_3 (4 t ha^{-1} vermicompost + High level of NPKS) treatment except for K in grain which showed highest value (0.474, %) in V_2F_3 (2 t ha^{-1} vermicompost + High level of NPKS). The lowest N, P, K and S contents (0.334, 0.98 %), (0.149, 0.19 %), (0.295, 1.88 %) and (0.104, 0.14%), respectively) were recorded with V_0F_0 treatment.

The post-harvest soil properties such as organic matter, total nitrogen, available phosphorous, exchangeable potassium and available sulphur contents were increased due to the combined application of vermicompost and NPKS fertilizers.

References

REFERENCES

Adeniyan, O. N. and Ojeniyi S. O. (2003). Comparative effectiveness of different levels of poultry manure in the N.P.K. fertilizer and residual soil fertility nutrient uptake and yield of maize.*Moor J. Agric. Res.* **4**(2): 191-197.

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

Aggelides, S. M., and Londra, P. A. (2000). Effects of compost produced from town wastes and sewage sludge on the physical properties of a loamy and a clay soil. *Bioresource Technol.* **71**(3): 253-259.

Agrawal, S. B. Singh, A., Singh, G. D. and Dwivedi, A. (2003). Effect of vermicompost, farmyard manure and chemical fertilizers on growth and yield of wheat (*Triticum aestivum* L. var. HD 2643). *Plant-archives.* **3**: 9-14.

Ahmed, S. R. and Reddy, P. V. K. (2002). Optimizing fertilizer doses for rice in alluvial soils through chemical fertilizer, FYM and GM using soil test values. *Agropedology*. **12**(2): 133-140.

Akanbi, W. B., Illupeju, E. A. O, Togun, A. O. and Adeyeye, S. A. (2010). Effects of Nigerian commercial organic fertilizers compost and NPK on maize performance, plant and soil nutrient content.*Intl. J. Organic Agric. Res. Dev.* **1**(1): 135-149.

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

Amin, M. (2004). Judicious fertilizer N split for higher use efficiency in transplanted rice. *Indian. J. Agric. Res.* **35**(4): 278-280.

Anand, S., Yaduvanshi, N. P. S. (2000). Effect of integrated nutrient management on soil properties and yield of rice in alkali soil. *J. Indian. Soc. Soil Sci.* **48**(2): 279-282.

Ande, O. T., Ayoola, O. T., Senjobi, B. A. and Adediran, J. A. (2010). Increasing maize yield on a degraded soil using organic and inorganic fertilizers. In: proceedings of the 34th Annual Conference of the Soil Science Society of Nigeria, March 22-26th, 2010,Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria. pp. 143-148.

Aptosol, E. D. F. (1989). Influence of mirasoil organic and x-rice liquid fertilizer in combination with inorganic fertilizer on IR66 and BRRI 12 rice varieties, Malabon, Metro Manila, Philippines: 73.

Arancon, N. Q., Lee, S., Edwards, C. A. and Aziyeh, R. M. (2003). Effect of humic acids and aqueous extracts derived from cattle food and paper waste vermicomposts on growth of green house plants. *Pedobiologica.* **47**(5-6): 741-744.

Arif, M., Tasneem, M., Bashir, F., Yaseen, G. and Iqbal, R. M. (2014).Effect of integrated use of organic manures and inorganic fertilizers on yield and yield components of rice. *J. Agric. Res.* **52**(2): 197-206.

Aulkah, M. S., Doran, J. W., Kuldip, S. and Singh, B. S. (2000). *Soil sci. American. J.* **64**(5): 1867-1876.

Awan, T. H., Ali, R. I., Manzoor, Z., Ahmad, M. and Akhtar, M. (2011). Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety, KSK-133. *J. Anim. Plant Sci.* **21**: 231-34.

Ayeni, L.S. Omole, T, Adeleye, E.O. and Ojeniyi, S. O. (2010). Integrated application of poultry manure and NPK fertilizer on performance of tomato in derived savanna transition zone of South-West Nigeria. *Sci. Nat.* **8**(2): 50-54.

Ayoola, O. T. and Makinde, E. A. (2009). Maize growth, yield and soil nutrient changes with N enriched organic fertilizers. *African J. food, Agric. Nutri. Dev.* **9**(1): 580-592.

Ayoub, A. T. (1999). Fertilizer and environment. *Nutr. Cycl. Agroecosys.* **55**: 117-21.

Azim, U. H. (1999). Effect of different doses of N, P, K & S on the yield of BR 11 variety of rice. In: Variety, Fertilizer and Weedicide Trial of some Field crops. Rural Development Academy, Bogra, 15-20.

Aziz, T., Ullah, S., Sattar, A., Nasim, M., Farooq, M. and Mujtabakhan, M. (2010).Nutrient Availability and Maize (*Zea mays*) Growth in Soil Amended with Organic Manures. *Intl. J. Agric. Biol.* **12**(4):621-624.

Babu, S., Marimuthu, R., Manivanna, V. and Kumer, S. R. (2001). Effect of organic and inorganic manures on growth and yield of rice. *Agril. Sci. Dig.* **21**: 232-34.

Bahman, E., Daniel, G. and John, E. G. (2004).Residual effects of manures and compost application on corn production and soil properties. *Agron. J. American Soc. Agronomy*. **96**: 442-447.

Bai, B. A. and Malakouti, M. J. (2007). Agricultural and Natural Resources Research centre of East Azarbajan. *Iranian J. Soil Water Sci.* **21**(1): 33-43.

Banerjee, H., Pal, S. and Maiti, S. (2006). Integrated effect of organic and inorganic fertilizer on the productivity and profitability of rice grown under rice-rice crop sequences in the Gangetic West Bengal. *J. crop weed.* **2**(1): 40-44.

Bangar, K. C., Shanker, S., Kapoor, K. K. Kukreja, K. and Mishra, M. M. (1990). Preparation of nitrogen phosphorous enriched paddy straw carry out and its effect on yield and nutrients uptake by wheat. *Biol. Fert. Soils*. **8**(4): 339-342.

Banik, P. and R. Bejbaruah. (1996). Effect of vermicompost on rice (*Oryza sativa* L.) yield and soil fertility status of rainfed humid sub-tropics. *Indian J. Agric. Sci.* Available:http://www.cababstractsplus.org.

BARC (Bangladesh Agricultural Research Council). 2012. Fertilizer recommendation Guide 2012. BARC, Soils Pub. No-14. 2012. Farmgate, Dhaka. 25-128.

Barik, A. K., Das, A., Giri, A. K. and Chattopadhaya, G. N. (2006). Effect of integrated plant nutrient management on growth, yield and production economics of wet season rice (*Oryza sativa L.*). *Indian J. Agric. Sci.* **76**(11):657–660.

Baron, R., Benitez, I. C. and Gonzalez, J. L. (1995).The influence of organic matter additions on wheat cultivation. *Agrochimica.* **39**(5): 280-289.

BBS (Bangladesh Bureau of Statistics). (2011). Statistical Year Book of Bangladesh. Bangladesh Bur. Stat. Div. Min. Plan., Govt. Peoples Repub. Bangladesh. pp. 1-330.

Becker, M., Ladha, J. K. and Ali, M. (1995). Green manure technology: potential usage, limitations: a case study for low land rice. *Plant Soil.* **174**: 181-94.

Bhadoria, P. B. S., Prakash, Y. S., Kar, S., Amitava, R. and Rakshit. A. (2003). Relative efficiency of organic on rice production lateritic soil. *Soil use manag.* **19**(1): 80-82.

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

Bharadwaj, V. and Omanwar, P. K. (1994). Long-term effects of continuous rotational cropping and fertilizer on crop yield and soil properties II. Effects on EC, pH, organic matter and available nutrients of rice. *J. Indian Soc. Soil Sci.* **42**: 387.

Bhattacharyya, P., Chakrabartik, and Chakraborty, A. (2005). *Chemosphere.* **60**(2-5): 310-318.

Bhuiyan, N. I. (1994). Crop production trends and need of sustainability in agriculture. Paper presented at the workshop. Integrated Nutrient Management for Sustainable Agriculture held at SRDI, Dhaka, Bangladesh in June 26-28.

Biswas, P. K. (1987). A study on the relative merits of mixed cropping under two levels of irrigations. MS Thesis, Dept. Agron. Sher-e-Bangla Agric. Univ. Mymensingh. pp. 38-40.

Black, C. A. (1965). Methods of Soil Analysis, Part-I and II. *Amer. Soc. Agron.* Inc. Pub. Madison, Wisconsin, U.S.A.

Blaise, D. and Rajendra, P. (1996). Relative efficiency of modified urea fertilizers in wetland rice (*Oryza sativa*). *Indian J. Agron.* **41**: 373-378.

Bodruzzaman, M., Meisner, C. A., Sadat, M. A. and Hossain, M. I. (2010). Long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern.19th World Congress of Soil Science, Soil Solutions for a Changing World 1–6 August 2010, Brisbane, Australia. pp. 23-44.

Brady, N. C. and Weil, R. R. (1999). The nature and properties of soil 12th ed.

BRRI (Bangladesh Rice Research Institute). (1987). Response of nitrogenous fertilizer on rice variety.Intertinal review. Bangladesh Rice Res. Inst. Joydebpur, Gazipur, Dhaka. p. 321.

BRRI (Bangladesh Rice Research Institute). (2004). BRRI Annual Report for July 2003-June 2004. Bangladesh Rice Res. Inst., Joydevpur, Gazipur, Bangladesh. pp. 55-59.

Budhar, M. N., Palaniappan, S. P and Rangaswamy, A. (1991). Effect of farm wastes and green manures on low land rice. *Indian J. Agron.* **36**(2): 251-252.

Chander, S. and Pandey, J. (1996). Effect of herbicide and nitrogen on yield of scented rice (*Oryza sativa*) under different rice cultures. *Indian J. Agron.* **41**(2): 209-214.

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

Chettri, M. Mondal, S. S. and Roy, B. (2002).Studies of the effect of sources of potassium and sulphur with or without FYM on the yield components, grain yield and percent disease index of rice under intensive cropping systems. *J. Interacademicia*. **6**(1): 45-50.

Chideshwari, T. and Savithri, P. (2000). Effect of organic and inorganic phosphatic fertilizers on the yield and status of P by rice. *Advances plant sci*. **13**(29): 643-647

Chideswari, T. and Krisnaswamy, R. (2005). Transformation of zinc enriched organic manures and the yields of rice ADT 36. *Advances Plant Sci*. **18**(1): 207- 212.

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

Dada, O. A., Togun, A. O. and Adediran, J. A. (2014). Growth, Nutrient Uptake Efficiency and Yield of Upland Rice as Influenced by Two Compost Types in Tropical Rainforest-Derived Savannah Transition Zone. *Agric. Sci.* **5**: 383-393.

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

Das, P. K., Jen, M. K. and Saoo, K. C. (2002).Effect of integrated application of vermicompost and chemical fertilizer on growth and yield of paddy in red soil of South Eastern Ghat Zone of Orissa. *Enviorn. Ecology*. **20**(1): 13-15.

Dash, D., Patro, H., Tiwari, R. C. and Shahid, M. (2011). Effect of organic and inorganic sources of N on growth attributes, grain and straw yield of rice (*Oryza sativa* L.). *Intl. J. Pharm. Life Sci.* **2**(4): 655-660.

Datta, J. K., Dasgupta, M. K.(ed.), Ghosh, D. C. (ed.), Dasgupta, D. (ed.), Chattopadhyay, G. N. (ed.), Ganguli, P. K. (ed.), Munsi, P. S. (ed.) and Bhattacharya, D. (1995). Effect of different chemicals, bio and industrial wastes on growth and yield on rice. Proceedings National Symposium on Sustainable Agriculture in Sub-humid Zone, March 3-5, pp. 140-141.

Datta, M. and Banik, S. (1994). Effect of poultry manure and phosphate dissolving bacteria on rice (*Oryza sativa*) in acid soil. *Indian J. Agril. Sci.* **64**(1): 791-793.

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

David, M. S. and Biswas, O. R. (1996). Use of phosphorous, poultry manure, biogas slut-n and FYM on dry- matter yield and utilization of P by wheat. *J. Nucl. Agril. Bio*. **25**(2): 89-93.

Dekhane, S. S., Patel, D. J., Jadhav, P. B., Kireeti, A., Patil, N. B., Harad, N. B. and Jadhav, K. P. (2014). Effect of organic and inorganic fertilizer on growth and yield of paddy CV GR 11. *Intl. J. Info. Res. Review.* **1**(2): 26-28.

Dey, P. and Jam, M. (2000). Use of urea enriched green manuring for their efficiency to sustain productivity of rice-wheat system. *J. Indian Soc. Soil Sci.* **48**(1): 102-107.

Doran, J. W., Sarrantonia, M. and Liebig, M. (2008). Soil health and sustainability. *Advances Agron.* **56**(1): 25-45.

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

Ebaid, R. A. and El-Refaee, I. S. (2007). Utilization of rice husk as an organic fertilizer to improve productivity and water use efficiency in rice fields. *African Crop Sci. Conf. Proc.* **8**: 1923-28.

Egbuchua, C. N. and Enujeke, E. C. (2013).Effects of Different Levels of Organomineral Fertilizer on the Yield and Yield Components of Rice (*Oryza Sativa* L.)In A Coastal Flood Plain Soil, Nigeria. *IOSR J. Agric. Veterinary Sci.* **4**(2): 1-5.

Elsharawy, M. A. O., Aziz, M. A., Laila and Ali, K. M. (2003). Effect of the application of plant residues composts on some soil properties and yield of wheat and corn plants. *Egyptian J. Soil Sci.* **43**(3): 421-434.

Encyclopedia Britannica. (2009). Rice studies (home edition) Chicago, USA.

Eneji, A. E., Honna, T. and Yamamoto, S. (2001). Manuring effect on rice grains yield and extractable trace elements in soils. *J. Plant Nutrition.* **24**(7): 967-977.

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

Fashola, 0. and Ogungbe, P. W. (2007). Growth and yield response of some maize cultivars to organomineral fertilizer application in simulated degraded soil under greenhouse conditions. *Nigerian J. Soil Sci.***17**:89-93.

Garai, T. K., Datta, J. K. and Mondal, N. K. (2013). Evaluation of integrated nutrient management on boro rice in alluvial soil and its impacts upon growth, yield attributes, yield and soil nutrient status. *Archives Agron. Soil Sci.* DOI:10.1080/03650340.2013.766721.

Gardner, Y. P., Gill, P. S. and Shahi, H. N. (1985). Effect of Nitrogen levels in relation of age of seedlings and time of transplanting oil growth yield and milling characteristics of rice. *Indian J. Agric. Sci.* **57**(9):6310-614.

Ghosh, B. C., Ranhavaian, C. V. and Jana, M. K. (1991).Effect of seed rate and nitrogen on growth and yield of direct sown rice (*Oryza sativa* L.) under intermediate deep water condition. *Indian J. Agron.* **36**: 227-228.

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

Google Maps. (2014). Google maps by Google Inc. [https://maps.google.com]

Gorlitz, H. (1987). Studies on the influence of soil humus status on yield components and crop yield. Cited from Field Crop Abst. **40**(11): 780.

Guera, R. D. (2010). Vermicompost production and its use for crop production in the Philippines. *Intl. J. Global Environ.* **10**(3-4): 378-383.

Gupta, S.K. (1995). Effect of organic manures on rice yield and moisture retention in Alfisol Soil. *J. Hill Res.* **8**(2): 169-173.

Haque, M. Q., Rahman, M. H., Fokrul, I., Jan, Rijmpa and Kadir, M. M. (2001). Integrated nutrient management in relation of soil fertility and yield sustainability under Wheat- Mung-T. aman cropping pattern. *J. Biol. Sci.* **1**(8): 731-734.

Havlin, J. L., Tisdale, S. L., Beaton, J. D. and Nelson, W. L. (2006). Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Seventh edition. Prentice-Hall of India, New Delhi. p. 515.

Hirst, K. K. (2006). History of rice: Archaeological evidence of the history of rice http://archaeoloqy.about.com%odidomestications/alrice.html

Hoque, M. A. (1999). Response of BRRI dhan29 to S, Zn and B supplied from manures and fertilizers. M.S. Thesis. Dept. of Soil Sci. (January-June Semester), 1999, BAU.

Hossaen, M. A., Shamsuddoha, A. T. M., Paul, A. K., Bhuiyan, M. S. I. and Zobaer, A. S. M. (2011). Efficacy of different organic manures and inorganic fertilizer on the yield and yield attributes of Boro rice. *The Agriculturists.* 9(1&2): 117-125.

Hossain, M., Singh, V. P. (2000). Fertilizer Use in Asian Agriculture: Implications for Sustaining Food Security and the Environment. *Nutr. Cycl. Agroecosys.* **57**(2): 155-169.

Hundal, H. S. Dhillon, N. S. and Dev, G. (1992). Contribution of different green manures to P nutrition of rice. *J. Indian. Soc. Soil Sci.* **40**: 76-81.

Hunt, J. (1980). Determination of total sulphur in small amount of plant material analyst. **105**: 83-85.

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

Hussain, A., Islam, M. R. and Mia, N. A. (1989).Response of rice to sulphur and Zinc fertilization, *Bangladesh J .Agril. Sci.***16**(2): 131-134.

Idris, M. (1981). Fertilizer use (Aman rice), Ann. Report, 1981-82. EHYVR. BAU. Mymensingh.

Islam, A. (1995). Review of Soil Fertility Research in Bangladesh. Proceeding of the Inter-Congress Conference of Commission IV. December 1-3, 1992 Dhaka.Improving Soil Management for Intensive Cropping in the Tropic and Sub-tropics.BARC.Pub. No. **37**: 1-18.

Islam, M. M. (1997). Response of BRRI dhan30 rice to cowdung and urea- N in the boro season. M.S. Thesis, Dept. Soil Sci. (January-June, 1997, Sem.), BAU, Mymensingh.

Islam, M. M. A. F., Khan, M. A., Bari, A. S. M. F., Hosain, M. T. and Sabikunnaher. (2013). Effect of fertilizer and manure on the growth, yield and grain nutrient concentration of boro rice (*Oryza sativa* L.) under different water management practices. *The Agriculturists.***11**(2): 44-51.

Islam, M. S. Amin, M. S. and Anwar, M. N. (1994). Integrated soil fertility management in Bangladesh. Paper-presented at the workshop on integrated nutrient management for sustainable agriculture held at *Soil Resour. Dev. Inst. Dhaka in June* 26-28. 1994.

Islam, M. S., Howlader, M. I. A., Rafiquzzaman, S., Bashar, H. M. K., and Al-Mamun, M. H. (2008). Yield response of chili and T. aman rice to NPK fertilizers in ganges tidal flood plain. *J. Soil Nature.* **2**(1): 7-13.

Islam, M. M. (1997). Response of BRRI Dhan 29 rice to cowdung and urea – nitrogen in the boro season. M.S Thesis, Dept. of Soil Sci., (Janu –June, 1997, Semi.), BAU, Mymensingh.

Issaka, R. N., Buri, M. M., Nakamura, S. and Tobita, S. (2014). Comparison of different fertilizer management practices on rice growth and yield in the Ashanti region of Ghana. *Agric. Forest. Fisheries.* **3**(5): 374-379.

Iwaishi, S. (2000). Effect of organic fertilizer and effective micro organisms on growth, yield and quality of paddy-rice varieties. *J. Crop-Production.* **3**(1): 269-273.

Jat, R. S. and Ahlawat, I. P. S. (2004). Direct and residual effect of vermicompost, biofertilizers and phosphorous on soil nutrient dynamics and productivity of chickpea-fodder maize sequence. *Indian J. Soil Sci.* **12**(2): 41-54.

Jeong, E. Shin, Y., Oh, Y., Choi, I., Shin, Y., Jeong, E. K., Shin, Y. B., Oh, Y. B., Choi, I. H. and Shin, Y. S. (1996). Effects of organic matter application on rice growth and grain quality. *J. Agril. Res.* **38**(1): 17-26.

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

Jobe. (2003). Integrated Nutrient Management for Increased Rice Production in the Inland Valleys of The Gambia. In: Sanyang S., A. Ajayi and A. A. Sy (eds). Proc. 2nd Biennial Regional Rice Research Review. WARDA Proceedings Series No. **2**(1): 35-41.

Kaleswari, R. K. and Subramanian, S. (2004). Impact of organic manure and organic phosphatic fertilizer on yield and nutrient uptake in a rice-rice cropping system. *Inter. Rice Res. Notes*. **29**(2): 57-60.

Kamiyama, K., Fujieara, S. and Funahashi, H. (1995). Effect of successive applications of cow manure compost on growth of crops and the chemical properties of soil.*Bull. Agril. Res. Inst. Kanagawa Prefect.* **136**: 31-42. Cited from Rice Abst. **18**(4): 278-995.

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

Khan, M. M. R. (1998). Effect of cowdun, poultry manure and urea-N on the growth and yield of BRRI dhan29. M.S. Thesis, Dept. Soil Sci. (July-December, 1998, Sem.), BAU, Mymensingh.

Khandal, D. K. and Nagendra, B. B. N. (2002). Effect of vermicompost of *Eichhrnia* on two cultivars of wheat.*J.Eco-Physiology*. **5**(3-4): 143-148.

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

Kumara, M. S. Kumari, S. K. U. (2002). Effect of vermicompost enriched with rockphosphate on growth yield of cowpea (*Vigna unguilata*). *J. Indian. Soc. Soil Sci.* **50**(2): 223-224.

Kusalkar, D. V., Awari, V. R., Pawar, V. Y. and Shinde, M. S. (2003). Physiological parameters in relation to grain yield in rabi sorghum on medium soil. *Adv. Pl. Sci.* **16**: 119-22.

Lima, J. S., .De. Queiroz and Freitas, H. B. (2004). Effect of selected and nonselected urban waste compost on the initial growth on corn. Resource, conservation and Recycling, Volume 42, Issue 4, November 2004. pp. 309-315.

Mahajan, A., Bhagat, R. M. and Gupta, R. D. (2008). Integrated nutrient management in sustainable rice-wheat cropping system for food security in India. *SAARC J. Agric.* **6**: 29-32.

Malviya, P., Jha, A. K. and Upadhyay, V. B. (2012).Effect of different proportions of vermicompost and fertilizers on growth and yield of scented rice and soil properties. *Ann. Agric. Res.* **33**(4): 228-234.

Manivannan, R. and Srirama chandrasekharan, M. V. (2009). Response of lowland rice to addition of organics and mineral N grown on Typic Haplusterts soil. *J. Applied Sci. Res.*7: 1988-1991.

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

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 Abst. **24**(6): 527-528.

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

McAndrews, G., Mattliebman, Cynthia, A., Cambardella, and Richard, T. L. (2006). Residual effects of composted and Fresh Solid Swine Manure on soybean growth, yield. *Agron J.* **98**: 873-882.

Meena, S. L., Surendra, S., Shivay, Y. S. and Singh, S. (2003). Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay loam soils. *Indian J. Agric. Sci.* **73**: 8-11.

Mendoza, T. C. (2002). Comparative productivity, profitability and energy use in organic. LEISA and conventional rice production in the Philippines. *Livestock Res. Rural Deve.* **14**(6): 1-16.

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

Miah, M. M. U. (1994). Prospects and problems of organic farming in Bangladesh. Paper presented at the workshop on integrated nutrient management for sustainable agricultute. Soil Reso. Dev. Ins. Dhaka. June. pp. 26-28.

Miah, M. A. M., Shah, A. L. and Ishaque, M. (2004). Nutrient management for different rice ecosystem. Proceedings of the workshop on modern rice cultivation in Bangladesh .Bangladesh Rice Research Institute, Gazipur, Bangladesh. **159**: 179-199.

Miller, H. B. (2007). Poultry litter induces tillering in rice. *J. Sustain. Agric.* **31**: 1-12.

Mirsha, V. K. and Sharma, R. B. (1997). Effect of fertilizer alone and in combination with manure on physical properties and productivity of entisol under rice-based cropping systems. *J. Indian .Soci. Soil Sci.* **45**(1): 84-88

Mirza Hasanuzzaman, K. U., Ahamed, N. M., Rahmatullah, N., Akhter, K. N., and M. L. Rahman. (2010). Plant growth characters and productivity of wetland rice (*Oryza sativa* L.) as affected by application of different manures. *Emir. J. Food Agric.* **22**(1): 46-58.

Mondal, S. S., Darmahapatra, A. N. and chaterjee, B. N. (1987). Effect of high rate of potassium and nitrogen on rice yield components. *Environ. Eco.* **5**(20): 300-303.

Mukhtar, T., Arif, M., Hussain, S., Tariq, M. and Mehmood, K. (2011). Effect of different rates of nitrogen and phosphorus fertilizers on growth and yield of maize. *J. Agric. Res.* **49**: 333-339.

Muthukrihsan, P., Chinnamuthu, C. R., Venkatakrishnan, A. S., Ponnuswamy, K. and santhi, P. (1998). Maximum yield research in transplanted irrigated rice. *J. Ecobio.* **10**(4): 313-315

Naing, A., Banterng, P., Polthanee, A. and Trelo-Ges, V. (2010). The effect of different fertilizers management strategies on growth and yield of upland black glutinous rice and soil property. *Asian J. Plant Sci.* **9**(7):414-422.

Narwal, R. P. and Chaudhary, M. (2006). Effect of long-term application of FYM and fertilizer N on available P, K and S content of soil. 18th World Congress of Soil Sci, Philadelphia, 9-15 July.

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

Ndaeyo, K. K. M. (2008). Nutrient management for soil fertility restoration and sustaining cropping system productivity.In Nutrient Management Practices in Crops and Cropping System. Sci. Pub., India. pp. 213-250.

Ohajianya, D. O. and Onyenweaku, C. E. (2002). Farm size and relative efficiency in rice production in Ebonyi State, Nigeria. A profit function approach AMSE Journal France. **25**(1): 28-42.

Ojeniyi, S. O. (2000). Effects of goat manure on soil nutrient content and Okra yield in rainforest area, Nigeria. *App. J. Tropic. Agric.* **51**: 20-23.

Ojeniyi, S. O., Makinde, E. A., Odedina, S. A. and Odedina, J. N. (2009). Effects of organomineral and NPK fertilizers on nutritional quality of Amaranthus in Lagos, Nigeria. *Nigerian J. Soil Sci.* **19**(2): 129-134.

Olatunji, O. and Ayuba, S. A. (2011). Effects of combined application of poultry manure and NPK 20-10-10 fertilizers on soil chemical properties and yield of maize (*Zea mays* L.). Proceedings of the 35th Annual Conference of the Soil Science Society of Nigeria. 7th-11th March, 2011, Minna, Nigeria.

Olowokere, F. A. (2004). Effects of different levels of poultry based organomineral fertilizer and weeding interval on the growth and yield of Okro. Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria. 6-10th Dec., 2004, Abeokuta, Nigeria.

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

Page, A. L., Miller, R. H. and Keency, D. R. (1982). Methods of soil Analysis. Part 2. 2nd ed. *Amer. Soc. Agron.*, Inc. Madi, Wis. USA.

Pandey, N., Verma, A. K., Anurag and Tripathi, R. S. (2007). Integrated nutrient management in transplanted hybrid rice (*Oryza Sativa* L.). *Indian J. Agron.* **52**(1): 40-42.

Pathak, H. M. C and Sarker, M. C. (1997). Nitrogen supplementation with straw in an ustochrept.

Phongpan, G., Vachrotayan, S. and Kumazawa, K. (1988). Rate and efficiency of urea fertilizer in wetland rice soil. *Soil Sci. Plant nutr.* **34**(1): 117-126.

Pontillas, L., Lugo, E., Malate, R. and Lanioso, A. (2009). Efficacy evaluation of vermicompost and inorganic fertilizer applied in lowland rice. *The Threshold.* **5**: 66-75.

Prabhahara Setty, T. K., Bandi, A. G., Singh, S. and Sanjay, M. T. (2007). Influence of Integrated Nutrient Management on growth and yield of hybrid rice under System of Rice Intensification (SRI) and Aerobic method of cultivation. In: SRI India 2007. Second National Symposium on System of Rice Intensification (SRI) in India-Progress and Prospects. Papers and Extended Summaries, 3-5th October, Agartala, Tripura, India, 82-84.

Prasad, B and Prasad, J. (1994). Integrated nutrients management for specific yield of rice (*Oryza sativa* L) based on targeted yield concept and soil test values in old alluvial soils. *Oryza.* **31**: 140-143.

Rabeya Khanam, Sahu, S. K and MItra, G. N. (1997). Yield maximization of rice through integrated Nutrient Management on Aeric Ustochrept. *J. Indian Society Soil Sci.* **45**(2): 396-397.

Radha Madhav. (1995). Relative efficiency of organic and inorganic sources of nitrogen on growth and yield of rice. M. Sc (Ag) thesis submitted to Acharya N G Ranga Agricultural University.

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

Rahman, S. and Parkinson, R. J. (2007). Productivity and soil fertility relationships in rice production systems, Bangladesh. Agricultural. *Systems.* **92**: 318-33.

Rahman. M. A. (2001). Integrated use of fertilizer and manure for crop production in wheat-rice and rice-rice cropping patterns Ph.D. Thesis. Dept. Soil Sci., Bangladesh Agril. Univ., Mymensingh.

Rakshit, A., Sarkar, N. C. and Debashish, S. (2008). Influence of organic manures on productivity of two varieties of rice. *J. Cent. Eur. Agric.* **9**(4): 629-634.

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* L.) under partially reclaimed sodic soil. *Indian J. Agric. Sci.* **70**(2): 114-116.

Ramalakshmi, Ch. S. Rao, P. C., Sreelatha, T., Mahadevi, M., Padmaja, G., Rao, P. V. and Sireesha, A. (2012). Nitrogen use efficiency and production efficiency of rice under rice-pulse cropping system with integrated nutrient management. *J. Rice Res.* **5**(1&2): 42-51.

Raman, R. K., Singh, M. P., Singh, R. O. and Singh, U. S. P. (1996). Long-term effet of inorganic and organic nutrient supply system of yield trends in rice-wheat cropping systems. *J. Appl. Biol.* **6**(12): 56-58.

Rani, R. and Srivastava, O. P. (1997). Vermicompost: a potential supplement to nitrogenous fertilizer in rice nutrition. *Intl. Rice Res. Notes.* **22**(3): 30-31.

Rani, R., Srivastava, O. P. and Rani, R. (2001). Effect of integration of organics with fertilizer N on rice and N uptake. *Fertilizer News.* 46: 63-65.

Ranjha, A. M., Ifftihkar, A., Iqbal, M. and Ahmed. M. J. (2001). Rice response to applied phosphorus, zinc and farmyard manure, *Intl. J. Agric. Biol.* **3**(2): 197-198.

Ranjitha, P. S., Kumar, R. M. and Jayasree, G. (2013). Evaluation of rice (*Oryza sativa* L.) varieties and hybrids in relation to different nutrient management practices for yield, nutrient uptake and economics in SRI. *Annals Biol. Res.* **4**(10):25-28.

Rao, K. R., Rao, P. A. and Rao, K. T. (2000). Influence of organic manur and fertilizers on the incidence of groundnut leafminer. ApproacremaModicellaDev. *Annals Plant Protection Sci.* **9**(1): 12-15.

Rasheed, M. H., Abedin, M. J., Rouf, M. A., and Eaqub, M. (2003). Residual effects of TSP and Farmyard manure under renewed application of urea on the yield of crop and some chemical properties of soil. *Bangladesh J. Agril. Sci.***10**(2): 100-109.

Razzaque, M. M. A. (1996). Comparative study on the effect of rice straw, farmyard manure and fertilizer nitrogen on the growth and yields of BR 11 rice. M.S. Thesis, Dept. Soil Sci. (January-June, 1996, Sem.), BAU, Mymensingh.

Reddy, B. G. M., Pattar, P. S. and Kuchanur, P. H. (2005). Response of rice to poultry manure and graded levels of NPK under irrigated conditions. *Bangladesh Res. publications J.* **2**: 552-558.

Reddy, G. R. S., Resddy, G. B. and Ramiah, N. V. (1986). Effect of rates and sources of nitrogen on transplanted low land rice. *Indian J. Agron.* **1**(1): 416-418.

Saha, S., Srivastava, O. P. and Rani, R. (2004).Effect of integration of organics with fertilizer N on rice and N uptake. *Fertilizer News.* **46**(9): 63-65.

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

Salem, A. K. M. (2006). Effect of nitrogen levels, plant spacing and time of farmyard manure application on the productivity of rice. *J. App. Sci. Res.* **2**(11):980-987.

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

Saleque, M. A., Panaullah, G. M., Zaman, S. K. and Bhuiyan, N. I. (1991). Residual effect of chemical fertilizer and rice straw on soil properties and yield of wetland rice. *Bangladesh J. Soil. Sci.* **22**(l&2): 17-24.

Salik, R., Sanjoy, S. and Ram, S. (1999). Economic of conjunctive use of organics and chemical fertilizer in rice crop grown under shallow lowland situation. *Oryza.* **36**(3): 286-287.

Santai, B. E., Daneshiyam, J., Amir, E. and Azarpour, E. (2011).Study of organic fertilizers displacement in rice sustainable agriculture. *Intl. J. Acad. Res.* **3**(2): 786.

Sarker, M. A. R., Pramanik, M. Y. A., Faruk, G. M. and Ali, M. Y. (2004). Effect of green manures and levels of nitrogen on some growth attributes of transplant aman rice. *Pakistan J. Biol. Sci.* **7**: 739-742.

Sarwar, G., Hussain, N., Schmeisky, H., Suhammad, S., Ibrahim, M. and Ahad, S. (2008).Efficiency of various organic residues for enhancing rice-wheat production under normal soil conditions.*Pakistan J. Bot.* **40**(5): 2107-2113.

Satyanarayana, V., Prasad P. V, Murthy, V. R. K. and Boote, K. J. (2002). Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *J. Plant Nutri.* **25**(10): 2081–2090.

Senanyake, N., Naylor, R. R. L. and Datta, S. K. D. (1996).Effect of nitrogen fertilization on rice spikelet differentiation and survival. *J. Agric. Sci.* **127**(3): 303-309.

Sengar, S. S., Wade, L. J., Baghel, S. S., Singh, R. K. and Singh, G. (2000). Effect of nutrient management on rice (*Oryza sativa*) in rain fed low land of Southeast Madhya Pradesh. *Indian J. Agron.* **45**(2): 315-322.

Setty, R. A and Channabasavanna, A. S. (1990). Fertilzers management in rice-rice sequence in Tungabadra Command area. *Oryza.* **2**(4): 461-464.

Sharma, D. K., Prasad, K. and Yadav, S. S. (2008). Effect of integrated nutrient management on the performance of dwarf scented rice (*Oryza sativa* L.) growth in rice wheat sequence. *Intl. J. Agric. Sci.* **4**(2): 660-662.

Siam, H. S., Abd El-Moez, M. R., Holah, S. H. and Abou Zeid, S. T. (2014). Ameliorative effect of organic and inorganic fertilizers under soil moisture regimes on growth parameters and yield of rice plants.*Intl. J. Sci. Res.* **3**(12): 2215-2221.

Siavoshi, M., Nasiri, A. and Laware, S. L. (2011). Effect of organic fertilizer on growth and yield components in rice (*Oryza sativa* L.). *J. Agric. Sci.* **3**: 217-24.

Singh, B. and Singh, Y. (2000). Poultry manure as an N source for wetland rice. Int. Rice Res. Newls.12 (6): 37-38.

Singh, B., Niranjan, R. K., and Pathak, R. K. (2001). Effect of organic matter resources and inorganic fertilizers on yield and nutrient uptake in rice wheat cropping system. *Inter. Rice. Res. Notes.* **26**(2): 57-58.

Singh, B., Singh, Y., Maskina, M. S. and Meelu, O. P. (1996).The valu of poultry manure for wetland rice in rotation with wheat. Nutrient cycling agro-ecosystem. **47**(3): 243-250.

Singh, H. J., Beyrouty, C. A., Norman, R. J. and N. A. (2003a). Influence of nitrogen fertilizer timing and rate on rice growth. Research Series Arkansas Agril. Expt. Station. **476**: 278-282.

Singh, H. J., Beyrouty, C. A., Norman, R. J. and N. A. (2003b). Influence of nitrogen fertilizer timing and rate on rice growth. Research Series Arkansas Agril. Expt. Station. **477: 87-89.**

Singh, L. N., Singh, R. K. K., Singh, A. H. and Chhangte, Z. (2005). Efficacy of urea in integration with Azolla and vermicompost in rainfed rice (*Oryza sativa* L.) production and their residual effect on soil properties. *Indian J. Agric. Sci.* **75**(1):44-45.

Singh, M. and Verma, S. C. (1971). Effect of different rates of nitrogen and phosphorus application on the yield and yield contributing characters of TN-1 rice. *Indian J. Agron.* **16**(3): 257–260.

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

Singh, R. and Agarwal, S. K. (2001). Analysis of growth and productivity of wheat in relation to levels of FYM and nitrogen. *Indian J. Plant Physiol.* **6**: 279-83.

Singh, S. K., Shahi, S. K., Singh, D. K. and Meena, V. S. (2014). Soil Properties and Productivity of Rice (*Oryza sativa* L.) as Influenced by Urea, FYM and Biofertilizers. *Annals Biol.* **30**(2): 335-339.

Singh, V. P. and Singh, R. K. (2000). Rainfed Rice: A Sourcebook of Best Practices and Strategies in Eastern India. International Rice Research Institute. 292 p.

Sinha, S. K., Verma, D. C. and Dwivedi, C. P. (2002). Role of green manure (sesbaniarostrata) and biofertilizer (Blue- green algae and Azotobactor) in rice-wheat cropping system in state of Uttar Pradesh, India. *Phy. And Mole. Bio. Plants.* **8**(1): 105-110.

Sohrab, A. and Sarwar, J. M. (2001).Production of vermicompost and its use in upland and horticulture crops. *Project report of Raj. Uni.*

Song, Y. and Yao, Z. (2001). Effect of application of fertilizer NPK combined with organic manure on growth characteristics and yield of winter wheat. *Beijing Agril. Sci.* **19**(5): 15-17.

SRDI (Soil Resource Development Institute). (1991). Land and Soil Resource Utilization Guide: Mymensingh Sadar Thana, Mymensingh. (In Bangali). SRDI, Ministry of Agricultural, Dhaka, Bangladesh. p. 3.

Subbalakshmi, L., Ravichandran, V., Suresh, S., Rabindran, R., Thiyagarajan, K. and Mohanasundaram, K. (2007) Efficient resource utilization in SRI method of Rice (CORH3) cultivation –An analysis. In: SRI India 2007. Second National Symposium on System of Rice Intensification (SRI) in India-Progress and Prospects. Papers and Extended Summaries, 3-5th October, Agartala, Tripura, India, 79-81.

Sujatha, V., Mosha, K., Subbaiah, G. and Rani, P. P. (2014).Residual soil fertility and productivity of rice (*Oryza sativa* L.) as influenced by different organic sources of nitrogen. *Intl. J. Plant, Animal Environ. Sci.* **4**(1): 266-269.

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

Tanaka, A. (1968). Historical changes in plant types of rice varieties in Hokkaido. *J. Sci. Soil manure.* **39**: 526-534.

Tejada, M. and Gonzales, J. L. (2008). Application of vermicompost on rice crop: Effects of biological properties and rice quality and yield. http://www.agron.scijournal. org/cgi/contents/abs

Tejada, M., Gonzaler, J. L. (2009). Application of two vermicompost on a rice crop: effects on soil biological properties and rice quality and yield. *Agron. J.* **10**(2): 336-344.

Thakur, R. B. (1991). Effect of N levels and forms of urea lowland rice under late transplanting. *Indian J. Agron.* **36**(2): 281-282.

Tilahun-Tadesse, F., Nigussie-Dechassa, R, Bayu, W. and Gebeyehu, S. (2013). Effect of farmyard manure and inorganic fertilizers on the growth, yield and moisture stress tolerance of rain-fed lowland rice. *American J. Res. Commun.* **1**(4): 275-301.

Tiwari, V. N., Hari, S. and Upadhyay, R. M. (2001). Effect of biocides, organic manure and blue green Algae on yield attributing characteristics of rice and soil productivity under sodic soil condition. *J.Indian. Soc. Soil Sci.* **49**(2): 332-336.

Tolanur, S. I. and Badanur, V. P. (2003). Effect of integrated use of organic manure, green manure andfertilizer nitrogen on sustaining productivity of Rabi sorghum-chickpea system and fertility of a vertisol. *J . Indian. Soc. Soil Sci.* **51**(1): 41-44.

Tripathy, R. K., Pandey, N., Mishra, P. K. and Rajput, R. S. (2004). Branching behavior and production of chickpea as influenced by residual effect of cowdung blended nutrients applied to hybrid rice and direct application of nutrients to chickpea under hybrid rice-chickpea cropping system. *Crop Res. (Hisar)*. **22**(2): 296-299.

Uddin, M. N., Chowdhury, M. Y. and Zaman, M. W. (2002). Effect of biogas effluent and cowdung with combinations of NPK fertilizer on the yield and protein content of wheat grain. *Bangladesh J. Sci. Indian Res.* **29**(2): 55-61.

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

Usman, M., Ullah, E., Warriach, E. A., Farooq, M. and Liaqat, A. (2003). Effect of organic and inorganic manures on growth and yield of rice variety "Basmati–2000". *Intl. J. Agric. Biol.* **5**: 481-83.

Vanjau, M. and Raju, A. S. (2002).Integrated nutrient management performance in rice crop.*Abbakas Agric. Res.* **2391**: 177-182.

Vasanthi, D. and Kumaraswamy, K. (2000).Efficacy of vermicompost to improve soil fertility and rice yield. *Indian J. Soc. Soil Sci.* **47**(2): 268-272.

Verma, T. S. (1991). Influence of lantana and Farmyard manure on paddy crop. The association of rice research workers. *Indian Oryza.* **28**(2): 177-183.

Vijaya, M. and Blasubramanian, K. A. (2002). Influence of nitrogen through integrated sources anic and inorganic on rice bast disease. *J. Myco. andPlant Patho.* **32**(2): 211-212.

Walkley, A. and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* **37**: 29-38.

Wells, B. R., Vories, E. Norman, B. J. and Kamputa, D. (1990). Nitrogen management of furrow irrigated rice. Res. Series-Arakansas Expt. Station. *398*:43-44.

Xu, M. G., Li, D. C., Li, J. M., Qin, D. Z., Yagikazuyuki and Hosen, Y. (2008). Effects of organic manure application with chemical fertilizers or Nutrient Absorption and yield of Rice in Hunan of Southern China. *Agril. Sci. China.* **7**(10): 1245-1252.

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

Yaqoob, M., Hussain, N. and Rashid, A. (2012). Assessment of genetic variability in rice (*Oryza sativa* L.) genotypes under rainfed conditions. *J. Agric. Res.* **50**: 311-19.

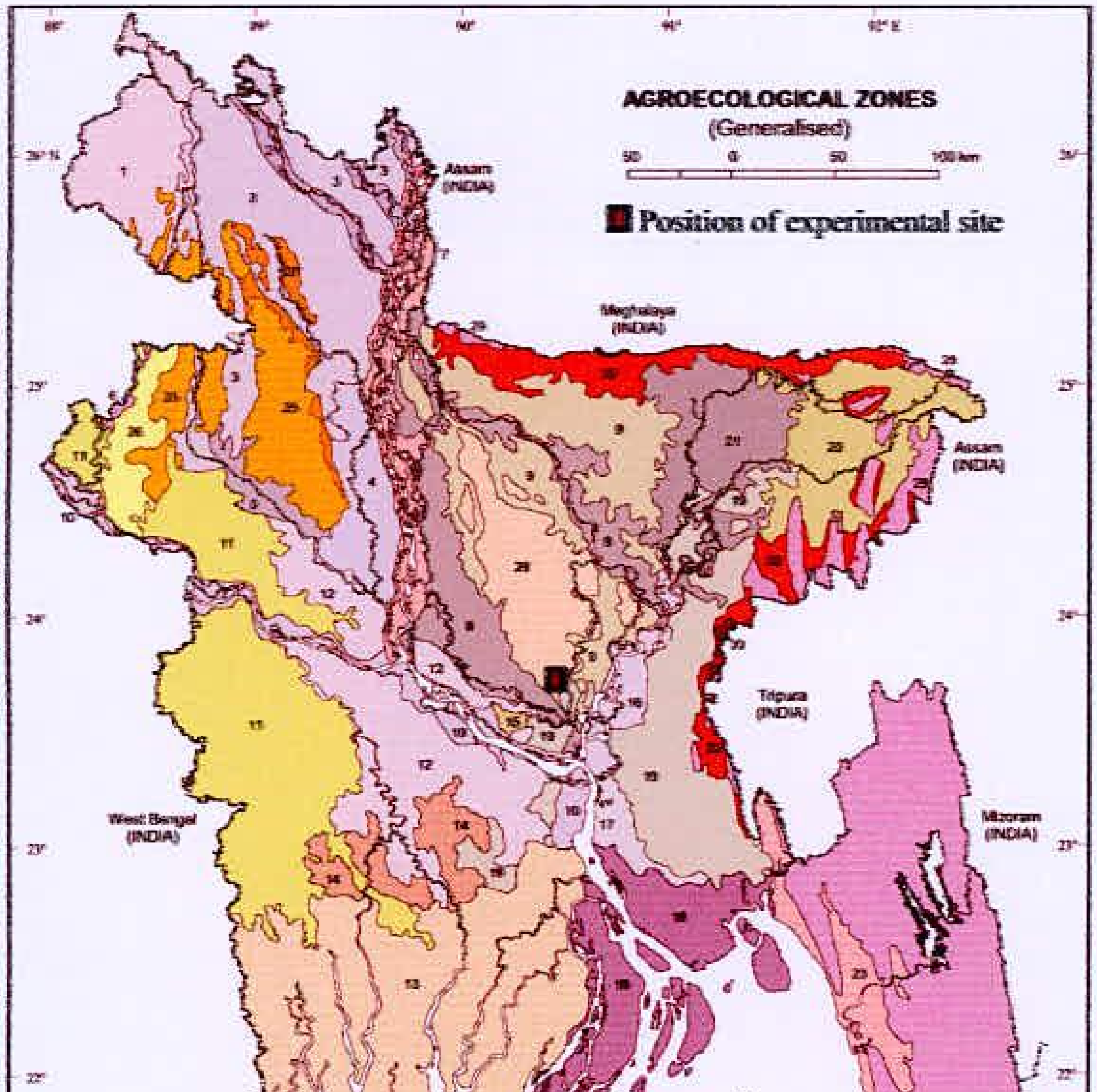
Yawalkar, K. S., Agarwal, J. P. and Bokde, S. (1981). Manures and fertilizers. 5th ed., Agric-horticultural Publishing House, Nagpur, 440010, Indian.

Zahid, H. M. (2001). Production of vermicompost and its use in upland and horticultural crops.Annual report of Bangladesh Agricultural Research Council, Farmgate, Dhaka.

Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. The morphological, physical and chemical properties of the experimental land

A. Morphological properties of the soil

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

(FAO and UNDP, 1988)

B. Physical properties of the soil

Physical properties	Value
Sand (%)	17.60
Silt (%)	47.40
Clay (%)	35.00
Porosity (%)	44.5
Texture	Silty Clay Loam
Bulk density (g/cc)	1.48
Particle density (g/cc)	2.52

C. Chemical composition of the initial soil (0-15 cm depth)

Chemical properties	Value
Soil pH	5.70
Organic Carbon (%)	0.89
Total N (%)	0.063
Available P (mg kg^{-1} soil)	14.90
Exchangeable K (meq/100 g soil)	0.12
Available S (mg kg^{-1})	11.0

Appendix III. Weather data, 2013-2014, Dhaka

Month	Average Relative Humidity (%)	Average Temperature (°C)		Total Rainfall (mm)
		Minimum	Maximum	
November	68.21	19.14	28.73	68
December	78.58	14.54	23.93	5
January	65.39	12.09	24.55	14
February	47.16	16.5	27.86	34
March	43.8	23.3	31.6	43.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.

Appendix IV. Mean square values for plant height, effective tillers hill^{-1}, non-effective tillers hill^{-1}, flag leaf length, panicle length and filled grains panicle^{-1} of rice

Sources of variation	Degrees of freedom	Mean Square					
		Plant height (cm)	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Flag leaf length (cm)	Panicle length (cm)	Filled grains panicle^{-1}
Replication	2	13.224	5.354	0.121	2.555	0.938	427.311
Vermicompost (A)	3	55.381**	6.176**	1.074**	7.430**	45.461**	2504.358**
NPKS fertilizer (B)	3	67.247**	23.026**	4.496**	21.861**	18.083**	7910.397**
Interaction (A×B)	9	4.717*	1.437*	0.170*	1.398*	1.334*	317.654*
Error	30	2.338	0.542	0.080	1.085	0.316	416.476

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

Appendix V. Mean square values for unfilled grains panicle^{-1}, 1000-grain weight, grain yield, straw yield, biological yield and harvest index of rice

Sources of variation	Degrees of freedom	Mean Square					
		Unfilled grains panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	11.269	50.142	4.540	1.097	6.588	71.733
Vermicompost (A)	3	17.881**	2.006**	9.531**	6.433**	29.167**	56.622**
NPKS fertilizer (B)	3	140.227**	10.695**	3.134**	7.882**	20.930**	8.475**
Interaction (A×B)	9	6.103*	1.191*	0.304*	0.082*	0.439*	4.766*
Error	30	1.767	1.221	0.122	0.145	0.278	3.904

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

Appendix VI. Mean square values for NPKS concentration in grain and straw of Boro rice

Sources of variation	Degrees of freedom	Mean Square							
		Concentration (%) in grain				Concentration (%) in straw			
		N	P	K	S	N	P	K	S
Replication	2	0.003	0.009	0.001	0.001	0.001	0.001	0.008	0.001
Vermicompost (A)	3	0.487**	0.025**	0.023**	0.009**	0.443**	0.003**	0.056**	0.003**
NPKS fertilizer (B)	3	0.445**	0.005**	0.002**	0.007**	0.419**	0.005**	0.539**	0.005**
Interaction (A×B)	9	0.015**	0.003**	0.001**	0.001**	0.006*	0.001**	0.022**	0.001*
Error	30	0.004	0.001	0.001	0.001	0.003	0.001	0.003	0.001

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

Appendix VII. Mean square values for organic matter and NPKS content in post harvest soil

Sources of variation	Degrees of freedom	Mean Square				
		Organic matter (%)	Total N (%)	Available P ($mg\ kg^{-1}$)	Exchangeable K ($mg\ kg^{-1}$)	Available S ($mg\ kg^{-1}$)
Replication	2	0.002	0.002	0.731	0.099	0.370
Vermicompost (A)	3	0.364^{NS}	0.001**	19.319**	54.442**	11.751**
NPKS fertilizer (B)	3	0.118^{NS}	0.001**	9.242**	42.926**	3.234**
Interaction (A×B)	9	0.019^{NS}	0.001**	0.164*	0.994*	0.114*
Error	30	0.001	0.001	0.155	0.177	0.060

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability NS: Non-significant

PLATES

Plate 2: Field view of the experimental plot

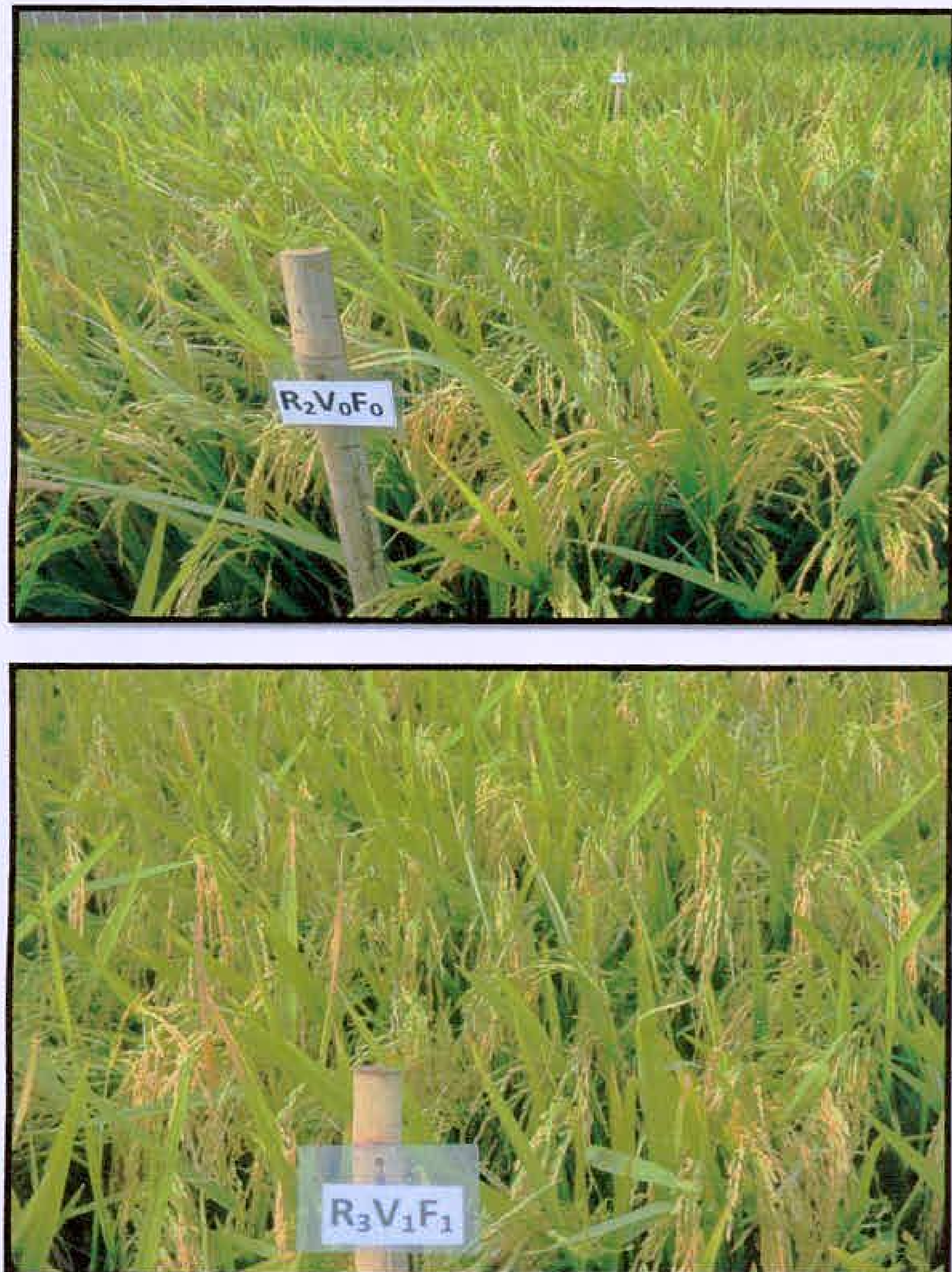


Plate 3: Field view showing different treatment combinations

Plate 3: Continued

Plate 3: Continued