EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON THE GROWTH, YIELD AND NUTRIENT UPTAKE BY RICE

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This is to certify that thesis entitled,"*EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON THE GROWTH, YIELD AND NUTRIENT UPTAKE BY RICE*" submitted to the Department of SOIL SCIENCE, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S) in SOIL SCIENCE , embodies the result of a piece of ***bona fide*** research work carried out by MD. ARIFUL HASAN, Registration No. 25155/00295 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated To

My Beloved Parents

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Kharif-1* season of 2005 to study the effect of organic and inorganic fertilizers on the growth, yield, nutrient concentration and uptake by rice. The experimental soil was silty clay in texture having pH of 5.9. The treatments were 4 levels of vermicomposts viz. V_0 (0 t ha^{-1}), V_1 (2 t ha^{-1}), V_2 (4 t ha^{-1}),V_3 (6 t ha^{-1}), and 4 levels of chemical fertilizers viz. F_0 = (0-0-0-0 kg ha^{-1} N, P_2O_5, K_2O, respectively), F_1 = low (50-40-30 kg ha^{-1} N, P_2O_5, K_2O, respectively), F_2 = medium (80-60-50 kg ha^{-1} N, P_2O_5, K_2O, respectively), F_3 = high (110-80-70 kg ha^{-1} N, P_2O_5, K_2O, respectively) with 16 treatment combinations and 3 replications. The results demonstrated that the increasing doses of vermicomposts and chemical fertilizers increased grain and straw yields of rice significantly. The maximum significant grain and straw yields were obtained with the treatment combinations, V_3F_2 . The optimum production of rice (BR-26,Shraboni) was obtained when 6 t ha^{-1} vermicompost combined with 80, 60, and 50 kg N, P_2O_5 and K_2O, respectively were applied. The highest doses of vermicompost and chemical fertilizers increased both the concentration and uptakes of N, P, K and S by rice plant significantly at the harvesting stage and showed highest values with V_3F_3 treatment combination. Application of chemical fertilizers alone failed to increase organic matter content of post harvest soil, whereas combined application of vermicompost and inorganic fertilizers showed a significant positive effect. Vermicompost and chemical fertilizers also increased N, P, K and S status of post harvest soil significantly.

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Chapter I

INTRODUCTION

Rice (*Oryza sativa*) is intensively cultivated in Bangladesh covering about 80% of arable land. Unfortunately the yield of rice in this country is very low (1.77 t ha^{-1}) compared to other rice growing countries like South Korea and Japan where the average yield is 7.00 and 6.22 t ha^{-1} , respectively (FAO, 1999). On the other hand, the demand for increasing rice production is mounting up to feed the ever increasing population.

Use of chemical fertilizers is an essential component of modern farming and about 50% of the world's crop production can be attributed to fertilizers use (Pradhan, 1992). The use of fertilizers in different countries of Asia has increased considerably with a maximum use of 509 kg $ha^{-1}yr^{-1}$ in the Republic of Korea as against only 102 kg $ha^{-1}yr^{-1}$ in Bangladesh (Khan *et al.* 1993). Nevertheless, sustainable production of crops can not be maintained by using only chemical fertilizers and at the same time it is not possible to obtain higher crop yield by using organic manure alone (Bair, 1990).

Soil organic matter is key factor for sustainable soil fertility and crop productivity. Organic matter undergoes mineralization with the release of substantial quantities of N,P,K & S and smaller amounts of micronutrients. Easily decomposable part of the soil organic matter undergoes quick mineralization and becomes a part of soil humus, a small portion of which may remain in soil for the long time. In Bangladesh, most of the cultivated soils have less than 1.0% organic matter while a good agricultural soil 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. Addition of organic matter in soil is a pre-requisite for efficient cycling of nutrients. Unless due attention is paid to the improvement and maintenance of soil organic matter it may not be possible to achieve the goal of increased and sustained productivity. Efforts need to be made to build up and maintain a moderate level organic matter in soil.

Organic farming is the management practice that produces crop of good quality and quantity by using eco-friendly technology, which can co-exist in nature. Such practices minimize the use of chemical fertilizers, pesticides and weedicides etc. The tussle between population growth and food supply in developing countries like Bangladesh are forced to cultivate repeatedly the high yielding varieties (HYV) of crops that leads to a rapid depletion of the soil nutrient reserve. To get more food, farmers are using chemical fertilizers and pesticides in increasing amount, which are making ecological backlashes, resulting in deterioration of soil health (Yawalkar, *et al.*, 1981).

Among the diffeent sources of organic manure, vermicompost is important in maintaining and enhancing the quality of environment and conserving resources for sustainable agriculture. Taking into account the environmental and public health benefits of vermicompost farming, there is a considerable potential to maximize the use of vermicompost to increase yield and to reduce unnecessary usages of chemical fertilizer for crops production in Bangladesh.

Several researchers have compared vermicompost with the surrounding soils and reported that have a higher base exchange capacity and are generally rich in total organic matter. Besides, it contains substances which helps in building soil structure, stimulation of plant growth, particularly that of roots, drilling mud and emulsifiers (Dussere, 1992). Soil organic matter improves the physicochemical properties of the soil and ultimately promotes crop production. Its status in Bangladesh soil is very poor. Evidences from different AEZ of the country have shown a decrease in the content of organic matter by the range of 15 to 30%

over the last 20 years (Miah,1994). Therefore, it is imposible to depend only on inherent potentials of soils for higher crop production. More recently, attention is focused on the global environmental problems; utilization of organic wastes, FYM, compost, vermicompost and poultry manures as the most effective measure for the purpose.

The application of different fertilizers and manures influences the physical and chemical properties of soil and enhance the metabolic activities of soil. The organic and chemical fertilizers are also positively correlated with soil porosity, enzymatic activity and CO_2 production. Organic matter stimulates soil biological activity, enhances soil porosity by increasing regular and irregular pores and causes a priming effect of native soil organic matter (Marinari *et al.*, 2000).

In Bangladesh, the farmers are using the chemical fertilizers continuously without knowing the actual dose and their residual effects on soil properties. Under these imbalanced conditions various beneficial soil microorganisms are being adversely affected. The soil is loosing its fertility as well as productivity day by day. If this trend continues, crop production will be seriously affected in the long run. On the contrary, if only organic matter is used the soil physical properties will be improved but the nutrient demand of the crop can't be satisfied due to low content of nutrients in organic matter.

So, combined applications of both chemical and organic fertilizers need to be applied for the improvement of soil physical properties and supply of essential plant nutrients. Information are limited regarding the combined application of organic and inorganic fertilizers with respect to the soil and crops of Bangladesh under the existing agro-climatic conditions which needs to be studied.

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

1. To study the effect of vermicompost and NPK on the yield of rice.
2. To know the optimum dose of vermicompost and NPK on the growth and yield of rice.
3. To see the improvement of soil fertility due to the use of vermicompost with NPK fertilizers.

Chapter 2

Review of Literature

Chapter 2
Review of literature

It is now realized that agriculture does not only refer to crop production but also to various other factors that are responsible for crop production. Vermicompost is one of the marvelous components in the organic farming and eco-friendly farming. Some of the published reports relevant to research topic are reviewed under the following headings:

2.1 Effect and importance of NPK fertilizers and manure application on rice

Meelu and Singh (1991) stated that besides chemical fertilizers, organic manure like poultry manure is a good source of nutrients in soil. Experiments on the use and agronomic efficiency of poultry manure showed that 4 t ha^{-1} poultry manure along with 60 kg N ha^{-1} as urea produced grain yield of rice similar to that with 120 kg N ha^{-1} as urea alone.

In Phillippines, Meelu *et al.* (1992) obtained 0.9 t ha^{-1} mungbean grain and considerable N saving with incorporation of mungbean straw before rice transplanting. The mungbean residue supplemented 25 kg ha^{-1} of inorganic N. This result suggests that mungbean or a similar short duration crop is an alternative to GM (Green manure). In this case, a farmer should consider growing leguminous crop that would produce a cash income. The crop residues should be incorporated in to the soil for its contribution of N and other nutrients.

Ali (1994) conducted experiment with rice at several locations of Bangladesh during 1989-90 showed fertilizer use efficiency of over 20 kg ha^{-1} nutrient supply. Improving the soil condition with organic manure and appropriate fertilization had further increased the production level of rice to more than 6 tons grain ha^{-1}.

Alam *et al.* (1994) conducted a field experiment on a sandy loam soil during 1990-92 to assess the effect of NPK with S and crop residues in a rice-wheat cropping sequence. The number of rice panicles increased due to addition of N in the fertilizer regime and by S plus crop residue. Grain development in both rice and wheat was improved due to addition of S. The yields of both rice and wheat crops where reduced in the absence of N.

Flynn *et al.* (1995) studied the residual effect of broiler litter as a supplemental of mineral N and concluded that broiler litter applied in autumn at the rate 9 t ha^{-1} reduced the mineral N from 44 kg to 22 kg ha^{-1}.

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 a 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}.

Gupta (1995) conducted field trial on different organic manure in India and reported that the application of green manure (10 t ha^{-1}) produced the highest grain yield (4.5 t ha^{-1}) followed by PM (Poultry Manure) and FYM (Farm Yard Manure) which produced yield of 4.1 and 3.9 t ha^{-1} of rice grain, respectively. The increase in rice yield with organic manure was 34 to 55% higher over control and 5 to 22% higher over NPK fertilizer.

Hama Singh and Sing (1995) showed that microbial biomass C, N and P were 66, 77 and 49% grater, respectively in the straw + fertilizer treated plots than in the control. Total crop biomass ranged from 6.79 - 9.91 t $ha^{-1}$and grain yield ranged from 1.08 -1.46 t ha^{-1} both in order control < Straw < fertilizer + straw: There were strong positive relationships between grain yield and microbial biomass, N- mineralization and available P.

Medhi *et al.* (1996) conducted a green house experiment to study the nutrients in soil and soil solution and growth of rice treated with organic manures and prilled Urea (P.U.). The nitrogen was applied at 60 kg N ha^{-1} and rice variety 'Ratna' was used as the best crop. Incorporation of organic and inorganic sources of N increased soil and soil solution NH_4^+ N to a peak and then declined to a very low level. The concentrations of P, K^+, Fe^{2+} in the soil and soil solution were higher with P.U. and organic source than control. Addition of N, regardless of sources, increased grain yield significantly. Nitrogen and Mn uptake by grain also increased significantly with the addition of N.

Jeon *et al.* (1996) studied the effect of PM (Poultry Manure) application on rice growth and grain yield quality. They reported that 5 t fermented chicken manure ha^{-1} in rice field increased N content in rice.

Singh *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, 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.

Mishra and sharma (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 in combination.

Rani and Srivastava (1997) showed that vermicompost (produced by earthworms from organic wastes) was tested in pot experiments for its ability to replace a proportion of the urea fertilizer applied to rice, compared with N fertilizer alone. Supplying one-third or one-quarter of N as vermicompost increased plant height, grain yield and yield components of rice.

Muthukrishnan *et al.*(1998) reported that the application of 100% or 133% of the recommended mineral fertilizer (150: 60: 60 NPK) 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 populations of 500000 plants ha^{-1}(20 x 10 cm spacing) and application of organic manure adjusted with mineral fertilizer.

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.

Aulakh *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 treatment. Nitrogen utilization by rice was greater for GM 20 than FN, as indicated by greater fertilizer N equivalents and an apparent N recovery by rice of 79 vs. 63%.

Rahaman (2001) conducted experiment with rice (Boro and T. Aman) with N, P, K, S and Zn fertilizers alone and with organic manures (Cow dung and Green Manure).The finding of his experiment suggest that the 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.

Singh *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 yields 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 were enhanced up to rates of 75% of the recommended NPK dosage 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 results 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.

Vijaya and Balasubramamian (2002) reported that 28 days old rice seedlings were treated with different organic amendments (Farm Yard Manure, at 50 kg N ha^{-1} + Urea at 50 kg N ha^{-1}, green manure and 50 kg N ha^{-1} + Urea at 50 kg N ha^{-1}, neem cake at 50 kg N ha^{-1} + urea at 50 kg N ha^{-1}, pressmud cake at 50 kg N ha^{-1} +Urea at 50 kg N ha^{-1}, and Urea at 100 kg N ha^{-1})in a field experiment conducted in Rudrur, India, during seasons of 1996 and1997 to develope a suitable integrated nutrient supply system to reduce blast (*Pyricularia orysae*) incidence in the crop. Substitution of nitrogen through FYM has a significant effect on reducing rice blast disease and increasing grain yield. Statistical analysis of the data showed that supply of 50% of the required nitrogen through FYM and remaining 50% through urea reduced the blast disease severity to a maximum extent and produced maximum yield.

Sinha *et al.* (2002) showed that application of BGA in combination with 90 kg N/ha recorded favorable results in all the three rice cultivars (Saryu-52, Swarna and Jaya) and was comparable with grain and straw yield at recommended doses of 120 kg N/ha. 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 green manure and BGA was also observed in wheat crops with Azotobactor at all levels of N. Maximum yield was recorded at 90 kg N ha^{-1} + Azotobactor.

Kaleeswari and Subramanian (2004) found that organic manures at 12.5 t ha^{-1} and inorganic phosphatic fertilizer i.e., single super phosphate (SSP) and udaipur rock phosphate (RUP) at 0, 30 and 60 kgP 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.

Gowda *et al.* (2004) conducted experiment that consisted of eight treatment including control; 5 and 10 t of fresh Azolla before planting; 5 and 10 t fresh Azolla + 30 kg N ha^{-1}; and 30, 60 and 90 kg N ha^{-1}. Rice varieties phalguna and Jaya were used in *Kharif* and *Rabi*, respectively. The experimental results indicated that the application of 10 t fresh Azolla + 30 kg N ha^{-1} and 90 kg N ha^{-1} recorded significantly maximum grain yield of 4719 kg ha^{-1}, height, tillers per hill and panicles /m^2 during *Kharif* as well as during *Rabi* season.

Singh *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 and straw yields were recorded with the application of 60 kg N ha^{-1} plus Azolla. They also found that the highest N, P and K uptake with the application of 60 kg N ha^{-1} plus Azolla treatment.

Chideshwari and Krishnawamy (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, 2.50, 3.75 and 5.0 mg/kg) were enriched with 4 sources of organic manures at 1.0 t ha^{-1} (farmyard manure (FYM), composted coir pith (CCP), FYM + green leaf manure (GLM amd CCP+ GLM) and was compared with the application of recommended dose of organic manures (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 the maximum yield compared to the recommended dose of organic manures. The enrichment of Zn at 1.25 mg/kg 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 crop growth (maximum tillering, panicle initiation and harvest).

2.2 Effect and importance of NPK fertilizers and manure on grain yield and nutrient uptake by rice

Bhandari *et al.* (1992) observed from a 4-year study on integrated nutrient management in a rice-wheat system that both rice and wheat yields continued to increase 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 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 pulse crop (mungbean) in the system substituted 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.

Khan *et al.* (1993) obtained rice yields of 3.2, 5.8 and 7.2 t ha^{-1} with 0, 60 and 120 kg N ha^{-1} when cop residues of mungbean were removed and 6.5, 7.5 t ha^{-1} residues were incorporated into the soil increased N and P uptake by rice.

Majid *et al.* (1995) found that when chicken manure was applied @) 0, 4.1, 8.25. to 15 and 33 t ha^{-1} in wheat, the grain yields, grain quality and straw yields were increased with the rate of chicken manure. The greatest economic return was recorded by 8.25 t ha^{-1}. The N and P uptake increased with increasing manure rates.

Kumar and Yadav (1995) studied the effect of organic manure, fertilizers and their integrated use in rice- wheat cropping sequence. In the first year, 25-50% substitution of fertilizers through organic sources, 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.

David and Biswas (1996) found that when 10 t PM ha^{-1} was applied with 120 kg P_2O_5 ha^{-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}.

Pathak and Sarkar (1997) studied the effectiveness 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 integrated use of conventional manure and urea. A very high dose of urea with rice straw was necessary to get good yield . At early growth stages of rice, straw-urea materials recorded higher N uptake but they failed to compete with manure in later stage. Use of 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 crop.

Dey and Jain (2000) observed the residual effect of GM and their enriched counterparts in terms of yield. N uptake and efficiencies of wheat was higher than that of urea treatment during preceding rice season. Quadratic models can effectively explain the variations in yield and N uptake of rice with N application up to 180 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.

Tiwari *et al.* (2001) found that the effect of farmyard manure (FYM), biocides (bitachlor, BHC (HCH) 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.

2.3 Effect and importance of NPK fertilizers and manure on grain yield and soil properties.

Prasad and Kerketta (1991) conducted an experiment to assess the soil fertility, crop production and nutrient removal under different cropping sequences in the presence of recommended doses of fertilizers and cultural practices along with 5 t ha^{-1} compost applied to the crops. There was an overall increase in organic C, total N (83.9%), available N (69.9%), available P (117.3%) and CEC (37.7%).

Bhandari *et al.* (1992) reported that an application of fertilizers or their combined use with organic manure increased the organic C status of soil. The NPK fertilizers at 100% level and their combined use with organic N sources also increased the available N and P by 5.22 kg and 0.8-3.8 kg ha^{-1} from their initial values.

Meelu *et al.* (1992) reported that organic C and total N increased significantly when *sesbania* and crotalaria were applied in the preceded rice crop for two wet seasons.

Nahar *et al.* (1995) had examined the soil condition after one crop cycle (rice-wheat). Addition of organic matter during the rice crop doubled the organic C content compared to its original status. Total and available N contents were also significantly improved by addition of organic matter, but had less impact on soil exchangeable cations.

Bellakki and Badanur (1997) reported from field experiments during 1984-94 that in situ incorporation of sun hemp reduced the bulk density as compared with fertilizer application. Application of sun hemp in combination with fertilizers improved the infiltration rate, water stable aggregates, porosity, field capacity and maximum water holding capacity under dry lands. Continuous application of organic fertilizer increased the ECE and exchangeable Ca while it decreased the Na and $CaCO_3$ contents. Available N, P, K and micronutrient contents increased significantly with organic sources of nutrients added either alone or in combination with fertilizers over fertilizers alone.

Rani and Srivastava (1998) conducted a pot experiment with application of fertilization and vermicompost and obtained highest grain yield and N uptake, when N, P_2O_5, and K_2O were applied at the rate of 60, 30 and 30 kg ha^{-1} with vermicompost.

Santhi *et al.* (1999) observed that application of 100% NPK plus FYM decreased the bulk density and increased the water holding capacity of soil. The decrease in bulk density in FYM treated plots might be ascribed to better aggregation. The water holding capacity increased due to the improvement of soil properties.

Vasanthi and Kumaraswamy K (2000) conducted field experiments on a red sandy clay loam soil with vermicompost at 5 and 10 t ha^{-1} with N, P and K at recommended levels. The result showed that the grain yields were significantly higher in the treatments that received vermicompost plus 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, K, micronutrients and cation exchange capacity were higher and bulk density was lower in the treatments that received vermicompost plus N, P and K than in the treatment with N, P and K alone. Vermicompost at 5 t ha^{-1} would be sufficient for a rice crop when applied with recommended levels of N, P and K.

Singh *et al.* (2001) conducted a field experiment to study the influence of organic fertilizers along with inorganic fertilizers on the rice-wheat cropping system. Five main-plot treatments viz., (M_1) green manure (sesbanga sesbana) , (M_2) Moong legume (vigna radiata) straw at (5 t ha $^{-1}$), (M_3) Farmyard manure (5 t ha $^{-1}$), (M_4) rice straw (5t ha $^{-1}$) and (M_5) weedy fallow;

and five sub plot treatments viz: (F_O) control, (F_1) 50% N, (F_2) 50% N P (F_3) 50% NPK and (F_4) 100% NPK of the recommended doses (120 kg N, 26.4 kg P and 49.8 kg K). Maximum grain yield was obtained (3.7 t ha $^{-1}$) in the plot of (M_1) while minimum grain yield was obtained (2 t ha $^{-1}$) under the fallow treatment (M_5).

Bajpai *et al.* (2002) found that green manure with prickly sesban or dhaincha *(Sesbania aculata)* to supplement 50% of the recommended nitrogen rate and the rest through inorganic fertilizer and 200% recommended rate of fertilizer to wheat crop gave the maximum yield of rice as well as wheat crops. The some treatment also gave the highest net returns and benefit: cost ratio, and produced significantly higher biomass in terms of rice equivalent yield. Among the organic manures, the overall performance of green manure was the best fallowed by farm yard manure and rice straw. The results showed a possibility of saving 50% fertilizer N in rice and 25% in wheat. Application of farmyard manure and rice straw as well as green manuring in rice significantly improved the available N and P status of soil.

2.4 Effect and importance of organic manure/crop residues on rice

Zhu *et al.* (1984) stated that the residual effect of GM was found to be more than those of urea as was evidenced by the increase in grain yields. N uptake and N recovery also showed positive effect of GM to the succeeding crops when applied to the preceding rice season

Maskina *et al.* (1986) conducted an experiment with different organic manure as a nitrogen source in rice-wheat rotation. They observed that yields with poultry manure and 80 kg urea-N ha $^{-1}$ was as high as those were with 160 kg urea-N ha^{-1} alone. Yields with FYM or pig manure and 80 kg fertilizer N ha $^{-1}$ were equal to 120 kg N ha $^{-1}$ fertilizer alone. They also reported that application of any one of the manure added to rice had residual effect equivalent to 30 kg N and 13 kg P ha $^{-1}$ in wheat.

In trial with rice-wheat cropping sequence Yadav *et al.* (1987) reported the highest yield with NPK as conventional fertilizers, intermediate yield with 50-75% NPK as conventional fertilizer plus 25-50% NPK as FYM and the lowest with all NPK as FYM. They found that the residual effect of NPK on wheat grain yield was in the order: FYM> conventional 75% NPK fertilizers FYM> conventional NPK fertilizers.

Bouldin (1988) viewed that the residual effects of green manure on a second crop would be small when only one application of green manure is made, but the cumulative effects of several annual applications are expected to give appreciable residual effects. These effects are important not only on N supply but also on long term improvement of soil fertility and crop productivity.

Ishikawa (1988) observed that long-term (10-15 years) application of vetch green manure increased organic matter and N contents of soils.

Garrity and Flinn (1988) conducted a regional survey in South Southeast and East Asian countries regarding green manure management systems. They concluded that that green manuring is now viable practice for rice farmers in many parts of Asia.

Ahmed and Rahman (1991) reported the residual effect of cow dung. In a treatment with cow dung and other sources of plant nutrients, they found significantly higher yield in the following crop from the plots which received cow dung in the previous rice.

Bhandari *et al.* (1992) demonstrated the residual effect of FYM. In a 4-year study on integrated nutrient management in rice-wheat cropping sequence some residual effect of

FYM on wheat was observed. Benoi *et al.* (1993) pointed out that the residual effect of FYM increased the grain yield of wheat by 230 to 520 kg ha^{-1}.

Rajput and Warsi (1992) examined the different levels of inorganic and organic sources of N in rice and residual effect of organic sources in the following wheat crop. They found that the residual effect of FYM alone increased the grain and straw yields significantly compared to the control.

Miah (1994) stated that only the first crop following the application of manure recovered one-fifth to one-half of the nutrients supplied by animal manure. The remainder was held as humus to very slow decomposition, 2.4% of nutrient element being released per annum.

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.

Santhi *et al.* (1999) reviewing green manuring research in India reported that the residual effect of green manure applied to rice was low. Previous works, (Beri and Meelu, 1981; Hesse 1984; Meelu *et al.*, 1992) have also shown that there is little or no cumulative (over 3 to 4 years) benefit of green manuring of rice to the succeeding crop.

2.5 Integrated use of fertilizers with manure / crop residues of rice

Maskina *et al.* (1986) studied the effect of N application on wetland rice in a loamy sand soil amended with cattle manure (60 kg N ha^{-1}) or PM (80 kg N ha^{-1}). In the absence of urea-N, PM increased the rice grain yield by 98%, which was 2.6 times higher than cattle manure (37%). Rice yield increased linearly with N rates whether or not the soil was amended with organic manure. Urea-N equivalent to cattle and PM varied from 21 to 53 and 50 to 123 kg ha^{-1}, respectively. Apparent recovery of N from poultry manure ranged from 38 to 82% compared with 51 to 69% from urea and 20 to 25% cattle manure and pig manure.

Besides chemical fertilizers, organic manure like poultry manure is another good source of nutrients in soil. Experiments on the use and agronomic efficiency of poultry manure showed that 4 t ha^{-1} poultry manure along with 60 kg N ha^{-1} as urea produced grain yield of rice similar to that with 120 kg N ha^{-1} as urea alone (Meelu and Singh. 1991).

Studies conducted by Ali (1994) with rice at several locations of Bangladesh during 1989-90 showed fertilizer use efficiency of over 20 kg per kg nutrient supply. Improving the soil condition with organic manure and appropriate fertilization had further increased the production level of rice to more than 6 tons grain ha^{-}

2.6 Residual effect of organic manure/ crop residues of rice

Residual effect of GM was found to be more than those of urea as was evidenced by the increase in grain yields, N uptake and N recovery. Zhu *et al.* (1984) also observed positive effect of GM to the succeeding crops when applied to the preceding rice season

2.7 Effect and importance of vermicompost on crop

Vermicomposting is the managed bioconversion of organic materials through earthworm consumption. Vermiculture and vercomposting experiments have been set up in many countries like England, France, Germany, Italy, Israel, USA, Japan, The Philippines, India and other parts of South-East Asia, Australia, Cuba, The Bahamas and many countries in Africa and South America (Edwards and Bohlen., 1996).

When vermicasts have been compared with the surrounding soils it is observed that casts have a high base exchange capacity and are generally rich in total organic matter, total exchangeable bases, phosphorous, exchangeable potassium, manganese and total exchangeable calcium. Vermicompost helps to improve and protect fertility of topsoil and also helps to boost up productivity by 40% with 20 to 60% lower nutrient inputs. It also enhances the quality of end products and thereby creating significant impact on flexibility in marketing as well as increases the storage time. Vermicompost contain 30 to 50% humic substances which help in the stimulation of plant growth, particularly that of roots, drilling mud and emulsifiers (Dussere, 1992).

A field experiment was conducted by Ranwa and Singh (1999) at Hisar, Haryana, India during the winter seasons of 1994-96 to study the effect of integration of nitrogen with vermicompost on wheat crop. The treatment comprised 5 levels of organic manures, viz., no organic manure, farmyard manure at 10 t ha^{-1}, vermicompost (at 5, 7.5 and 10 t ha^{-1}) and 4 levels of N viz. 0, 50, 100, 150 kg ha^{-1} and other recommended fertilizer dose. They reported that the application of organic manures improved yield attributes and grain, straw and biological yields of wheat. Application of vermicompost at 7.5 or 10 tha^{-1} resulted in higher yields than 10 t ha^{-1} FYM.

Vasanthi and Kumaraswamy (1999) from an experiment with vermicompost 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.

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 bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost.

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 one 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 were higher than the control and chemical fertilizer treated plots (Zahid, 2001).

A study was conducted in India 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).

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 fertilizes 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).

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 50 percent N through green manure plus 50 percent fertilizer N (Tolanur and Badanur., 2003).

2.8 Effect and importance of vermicompost on nutrient status and crop production

Kumari 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 solubilising and cellulose decomposing organisms.

Vermicompost contains 2.29 folds more organic carbon, 1.76 times total nitrogen, 3.02 folds phosphorous 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).

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).

The organic wastes could be efficiently converted into vermicompost with a recovery of 74.65 - 87% in a composting period of 3 months. Earthworm biomass was doubled irrespective of organic waste used in a period of 2 months. Major nutrients (NPK) and micronutrient (Cu, Zn, Fe and Mn) contents were slightly higher in all the vermicompost samples than in normal compost. Vermicompost had lower C : N ratio and pH than normal compost irrespective of the source of organic waste. Microbial population was considerably higher in vermicompost than in normal compost (Chowdappa *et al.*, 1999).

Earthworms influence the changes in various chemical parameters governing the compost maturity of local grass, mango leaves and farm wastes. There was a decrease in C : N ratio, while humic acid, cation exchange capacity and water soluble carbohydrates increased up to 150 days of composting. Compost maturation was achieved up to a period of 120 and 150 days in farm wastes and mango leaves, respectively, while more than 150 days would be required to reach the maturity in case of local grass. Inoculation of earthworms reduced the composting by 13 days (Talaskilkar *et al.*, 1999).

Vermicomposting of sugarcane trash individually and in combination with pressmud using earthworm *Perionyx excavatus* increased significantly N by 34%, P by 87%, K by 40%, Ca by 64%, Mg by 39% and Mn by 11% over the control compost along with a reduction in C :N (15 :1) and C : P (6 :1) ratio due to mineralization and combined action of earthworms and microbes (Ramalingam, 1999).

Saerah *et al.* (1996) conducted an experiment on the effect of compost in optimizing the physical condition of sandy soil. Compost at the rates of 0.0, 16.5, 33.0, 49.5 and 66.0 t ha^{-1} was incorporated into the soil and then wheat was grown. The results indicated that the various application rates were significantly correlated with improvement in physical properties of soil as well as straw and grain yields of wheat.

Robinson *et al.* (1992) reported that the nutrients present in vermicompost are readily available and the increase in earthworm populations on application of vermicompost and mulching leads to the easy transfer of nutrient to plants thus providing synchrony in ecosystems.

Harris *et al.* (1990) reported that earthworm excreta is the excellent soil conditioning material with higher water holding capacity and less time for releasing nitrogen into the soil. The nutrient level of the vermicompost was about two times greater than natural compost and the use of vermicompost is important for the farmers to get better quality crop yields.

Organic manure influences favorably plant growth and yield through augmentation of beneficial microbial population and their activities such as organic matter decomposition (Gaur *et al.*, 1971).

2.9 Effect and importance of NPK and manure application on other crops

Ganapathy (2006) reported that integrated use of organic and inorganic manures accelerated the growth and yield components of sunflower compared to inorganic fertilizer application. The growth was more with NPK+FYM compared to 100% NPK. The organic fertilizers in combinations with inorganic fertilizers were superior to sole inorganic fertilizer for growth and yield components. Overall application of 75% NPK and FYM @ 10 t/ha recorded highest seed yield and yield attributes (head diameter, number of seeds/head and 100-grain weight of sunflower).

A field experiment was conducted by Bayu *et al.* (2006) to assess the effect of the combined use of farmyard manure and inorganic fertilizer on the growth and yield of sorghum and on soil chemical properties in a semi-arid area in northeastern Ethiopia. The combined application of farmyard manure and inorganic fertilizers increased post-anthesis dry-matter production by 147%–390% and grain yield by 14%–36%. The main effects of farmyard manure and inorganic fertilizers increased stover yield by 8%–21% and 14%–21%, respectively. Farmyard manure application increased total nitrogen (N) uptake by 21%–36%, grain yield by 8%–11%, and grain protein concentration by 20%–29%. Application of farmyard manure along with 50% of the recommended inorganic fertilizer rate resulted in a grain yield equivalent to, or greater than that for 100% of the recommended inorganic fertilizer rate, thus affecting a 50% savings of inorganic N and phosphorus (P) fertilizer.

Jat and Ahlawat (2004) reported from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, India reported 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 bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost treatment.

The effects of NPK applied through various combinations of vermicompost, farmyard manure, and chemical fertilizers on the growth and yield of wheat were studied. The application of vermicompost significantly increased biomass production and yield of wheat. Treatment with 75% vermicompost + 25% farmyard manure resulted in the greatest plant height, leaf number, fresh weight, dry weight and number of spikelets per plant, number of seeds per spike, 1000 grain weight, grain yield per plot and harvest index (Agrawal *et al.*, 2003).

A field experiment was conducted by Rawat and Pareek (2003) with farmyard manure at 0, 5, 10 or 15 t ha^{-1} and NPK at 0 : 0 : 0, 30 : 20 : 10, 60 : 30 : 20, 90 : 40 : 30 or 120 : 50 : 40 kg ha^{-1} respectively in wheat crop in a field experiment conducted in Jobner, Rajastan, India during the *rabi* season of 1998-99 to determine the effects of FYM and NPK on the yield and nutrient uptake of the crop. The yield and NPK content of wheat grain and straw increased with increasing rates of FYM and NPK uptake of the crop also increased with increasing rates of FYM and NPK. The treatments had no significant effects on the organic carbon and available NPK content in the soil at harvest.

Tolanur and Badanur (2003) observed that the highest grain yield and stover yield of pearl millet was obtained with organic source of nutrients to meet 50% N in conjunction with 50% RDF(recommended dose of fertilizer) over control. N applied in two splits recorded the highest yield (1767 Kg ha^{-1}) followed by FYM to meet 50% N with 50% RDF (1744 $Kgha^{-1}$). They also observed that grain yield of pigeonpea recorded the highest grain yield (801 Kg ha^{-1}) with 50% N through subabul with 50% RDF. They also reported that 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 yield of *rabi* sorghum and chickpea was obtained with 50% N through green manure plus 5% fertilizer N.

The continuous use of organic manures along with inorganic fertilizers increased nutrient uptake and nutrient use efficiency of major nutrients than did the inorganic fertilizers alone (Baslar, 2003).

Application of organic manure i.e. vermicompost or FYM along with fertilizer NPK had beneficial residual effect in increasing yield, uptake of nutrients in wheat crop as well as available nutrient (NPK) in soil. The best treatment i.e. 50% NPK fertilizer along with vermicompost @ 10 t ha^{-1} was tested in farmers fields. (Kamla Kanwar., 2002).

Song *et al.* (2001) conducted an experiment with winter wheat in China to investigate the effects of application of chemical fertilizer NPK alone and combined with organic manure on the growth characteristics and yield of winter wheat. The application of fertilizer NPK alone or fertilizer NPK combined with various sources (FYM, wheat straw and maize straw) of OM increased the wheat's spike length, grains/spike, and plant height compared with the control treatment, thus enhancing biomass and grain yield of wheat. The application of fertilizer NPK combined with OM had a better yield increase than the application of fertilizer NPK alone, especially combined with farmyard manure at a higher dose. It is concluded that the application of fertilizer NPK combined with OM not only make good use of resources, but also enhance wheat yield.

Okalebo *et al.* (1999) observed in the Kenyan highland that maize grain yield ranged between 751 and 6836 kg ha^{-1} with lowest yields observed in the treatment receiving wheat straw alone and higher yields associated with soybean residue incorporation and during the second, wetter growing season. In 1998, crop benefited from more favorable rainfall, providing grain yield increase of 141% above control treatment as a result of combining 2 t ha^{-1} soybean trash and 100 kg N ha^{-1} as urea. Larger yields were obtained when organic and inorganic inputs were applied to soils, particularly when soil moisture was adequate and the organic inputs higher in mineralisable nutrients.

Baron *et al.* (1995) found that the addition of organic manure has a positive influence not only on soil properties but also on the mineral nutrition of plants and yield of wheat.

Gupta *et al.* (1996) performed an experiment on wheat cv. WH-157 and observed that grain yields and P and N uptake increased with increasing organic manure levels. Organic carbon content increased with the application of organic manure.

In a field experiment on a sandy clay loam in Tamil Nadu, sunflowers were given 0, 10, 20, 30 or 40 kg K_2O ha^{-1} basally or foliar application of 1.75% KCl at critical growth stages with 0 or 20 kg P_2O_5 ha^{-1}. P and K application increased seed yield and seed oil content. The highest seed yield (1.46 t ha^{-1}), seed oil content and benefit cost ratio were obtained with 40 kg K_2O + 20 kg P_2O_5. Soyabeans were grown after sunflowers on the same plots either with only residual fertilizers or with freshly applied P and K. Both residual and freshly applied fertilizers benefited the soyabean crop (Annaduri *et al.*, 1994).

A field experiment was conducted at Mymensingh, Bangladesh with wheat variety Kanchan with no mineral fertilizer, 110 kg N, 90 kg P or 100 : 90 : 40 kg NPK ha^{-1} and no manure or 8 or 16 t biogas effluent or cattle manure/ha. Average grain yields and protein contents were higher in plots treated with biogas effluent than with cattle manure or the control. Biogas effluent application resulted in the tallest plants, but straw production was highest with cattle manure. There was no significant difference between yields from plots treated with 8 or 16 t biogas effluent, and although yields increased with level of cattle manure, 8 t biogas effluents gave better results than 16 t cattle manure. Assessment of the manure treatments in combination with mineral fertilizers showed that 8 t biogas effluent + NPK gave the highest grain yield but 16 t biogas effluent + 100 kg N gave the highest protein content (Uddin *et al.*, 1994).

A study was conducted to determine the effects of some of the fertilizer and manure treatments on wheat yield and NPK uptake by wheat. The application of NP fertilizer with and without manure resulted in significant yield increases over the control. The application of NP-fertilizer and NP-manure increased grain-N from 2.03 (control) to 2.38 and 2.31, respectively. Individual and combined application of NP-fertilizer and manure produced a more pronounced effect on K concentration and uptake in straw than in grain (Baluch *et al.*, 1989).

Laboratory and field experiments were conducted by Guan (1989) to investigate the influence of organic manures on the availability of nitrogen and phosphorus in an alluvial soil in Shandong, China. The application of compost increased the availability of N and P in comparison with the control.

Srivastava *et al.* (1989) conducted a field experiment and observed that direct soil incorporation of organic wastes consisting of paddy straw and water hyacinth (50: 50) in combination with different levels of fertilizer N resulted in increased wheat yield and improved the organic matter and soil nitrogen status. The maximum yield was obtained with 5 t organic wastes plus 100 kg urea ha^{-1}.

Mehta and Dafterdar (1984) found that yield of wheat was greater when compost (4.4 t ha^{-1}) + NPK was used than when NPK alone was used.

Reddy and Reddy (1998) concluded that the combined use of VC(vermicompost) at 50% level of N with 50% N through inorganic fertilizer is suitable for maintaining good soil health and for obtaining optimum yields in maize- soybean cropping system.

Manna *et al.* (2001) observed in a 3-year field study (1996–99), the performance of four different composts obtained from legume straw (*Glycine max* Merr.L), cereal straw (*Triticum aestivum*), oilseed straw (*Brassica juncea* L.), city rubbish and compared with chemical fertilizers in terms of degree of maturity, quality of compost, improvement in soil organic matter, biological activities of soil and yields of soybean and wheat. The matured compost increased total P, water soluble P, citrate soluble P, total N and NO_3-N and the application of phosphocompost at the rate of 10 t ha^{-1} gave plant growth dry matter accumulation, seed yield and P uptake by soybean equivalent to single super phosphate at 26.2 kg P ha^{-1}.

Vyas *et al.* (2003) reported that combined application of 5 kg Zn and 10 t FYM ha^{-1} increased grain yield, NPK contents in and uptake by soybean seed. The highest grain yield (1790 kg ha^{-1}) was recorded in Zn +FYM treatment with a record of 18.2% increase over control (1515 kg ha^{-1}).

A long-term experiment was conducted by Behera (2003) during 1995-2002 under the fine-textured Vertisols at Indore, India to study the effect of combined use of Farm Yard Manure (FYM), poultry manure, vermicompost and biofertilizers (Azotobacter + phosphate solubilizing bacteria) with 50 and 100% NPK on wheat, and residual effect on following soybean. Grain yield of aestivum wheat in the initial 2 years and durum wheat in the later 3 years was significantly increased with 50% NPK + poultry manure @ 2.5 t ha^{-1} or FYM @ 10 t ha^{-1} compared with 50 or 100% NPK alone. Soybean did not show much response to residual effect of treatments in most years, although the yield were comparatively better under the combined use of 100% NPK +FYM or poultry manure given to wheat.

Reddy *et al.* (2004) conducted a field experiment on a Typic Haplustert from 1992 to 1995 where in the annual treatments included four rates of fertilizer P (0, 11, 22 and 44 kg ha^{-1} applied to both soybean and wheat) in the absence and presence of 16 t ha^{-1} of manure (applied to soybean only). They observed that with regular application of fertilizer P to each crop the level of Olsen P increased significantly and linearly through the years in both manured and unmanured plots. The mean P balance required to raise Olsen P by 1 mg kg^{-1} was 17.9 kg ha^{-1} of fertilizer P in unmanured plots and 5.6 kg ha^{-1} of manure plus fertilizer P in manured plots.

Hati *et al.* (2006) found that application of 10 kg farmyard manure and recommended NPK (NPK + FYM) to soybean for three consecutive years improved the organic carbon content of the surface (0–15 cm) soil from an initial value of 4.4 g kg^{-1} to 6.2 g kg^{-1} and also increased seed yield and water-use efficiency by 103% and 76%, respectively over the control. Root length density (RLD) up to the 30 cm depth was highest in the NPK + FYM plots and it was 31.9% and 70.5% more than NPK and control plots.

Ghosh *et al.* (2006) observed that yield and land equivalent ratio (LER) of the intercrops increased over sole crops though based on aggressivity and relative crowding coefficient (RCC), sorghum is more competitive than soybean. Soybean did not benefit from intercropping to the same degree as sorghum under N–P–K. Nutrient application influenced LER, RCC, and monetary advantage index and was found in the order of N–P–K plus farmyard manure (FYM) > N–P–K plus poultry manure (PM) > N–P–K plus phosphocompost (PC) > N–P–K > control. However, based on competition ratio, yield advantage was greater under N–P–K plus PM.

A long-term (30 years) soybean–wheat experiment was conducted by Kundu *et al.* (2006) at Hawalbagh, Almora and observed that maximum yields of soybean (2.84 Mg ha^{-1}) and residual wheat (1.88 Mg ha^{-1}) were obtained in the plots under NPK + farmyard manure (FYM) treatment, which were significantly higher than yields observed under other treatments.

A field experiment on maize with soybean intercropping system was conducted by Shil *et al.* (2007) during *rabi* season of 2005-2006. There were 8 treatments comprising 2 sets of planting geometry (PG_1 & PG_2) and 4 doses (NM_1, NM_2, NM_3 and NM_4) of nutrient management package. The interaction effect between planting geometry and nutrient management was statistically non-significant for the main crop (hybrid maize). In case of companion crop (soybean), the highest seed yield (564 and 504 kg ha^{-1}) was obtained with NM_3 x PG_2, which was significantly higher over rest of the combinations.

Chapter 3

Materials and Methods

Chapter 3

MATERIALS AND METHODS

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

3.1 Experimental site and location

The research work relating to the study of the effect of vermicompost and NPK on the growth, yield and nutrient uptake by rice was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Kharif-1* season of 2005. The following map shows the specific location of experimental site (Figure 1).

3.2 Description of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General soil type is Shallow Red Brown Terrace Soils. A composite 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 collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. Some initial physical and chemical characteristics of the soil are presented in Table 1.

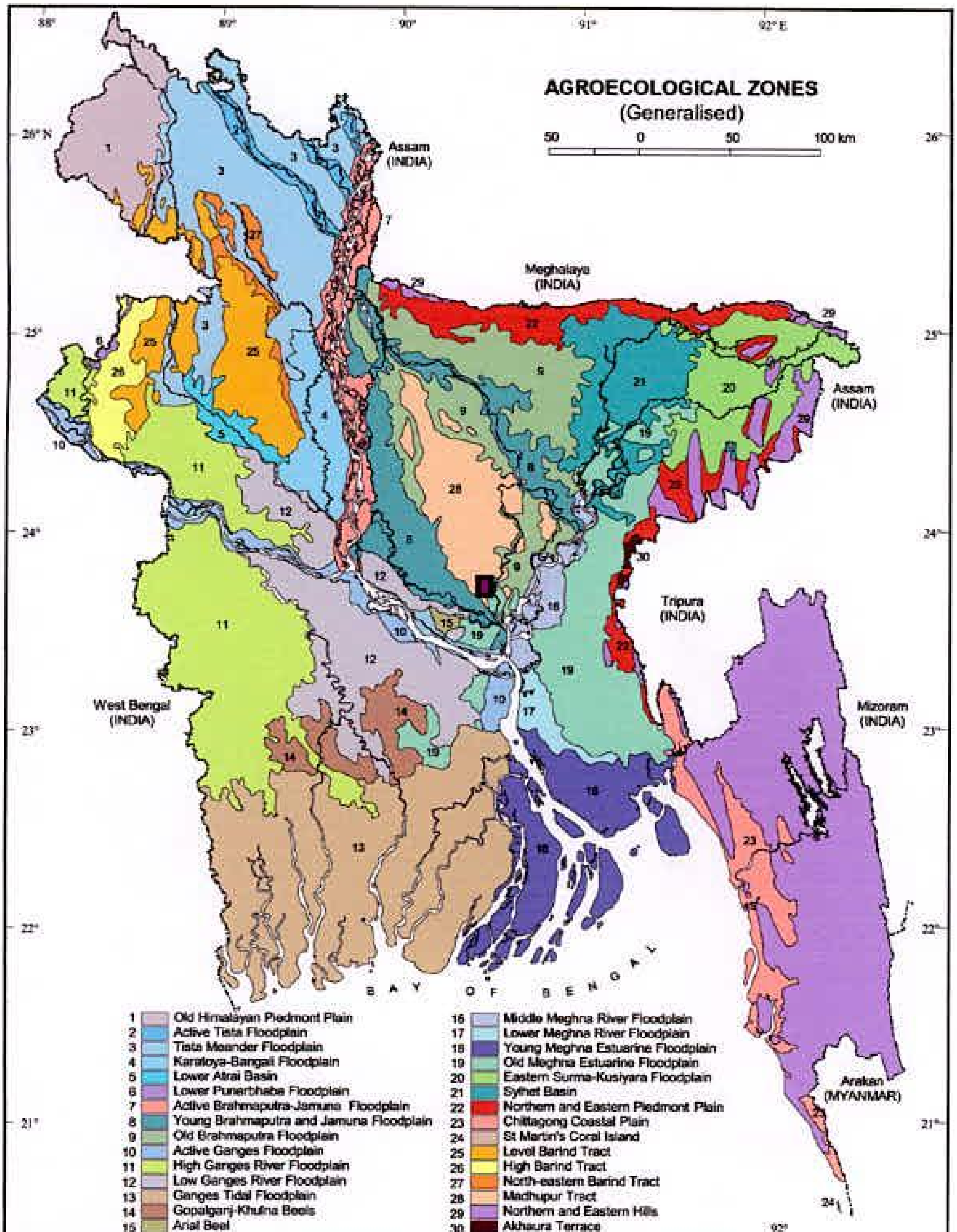


Figure 1. Map showing the experimental site under study ■

Table 1. Initial characteristics of the soil of the experimental field

1.pH		5.9
2. Particle-size analysis of soil	Sand	30.18
	Silt	38.05
	Clay	31.77
3. Textural Class		Silty clay
4. Total N (%)		0.083
5. Organic matter (%)		1.09
6. Phosphorous (%)		0.0014
7. Potassium (%)		0.00095
8. Sulphur (%)		0.00123

3.3 Description of the rice variety

Shraboni (BR-26), a high yielding variety of rice was used as the test crop in this experiment. This variety was released by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur in 1993. Life cycle of this variety ranges from 115 to 120 days. The variety is resistant to blast disease, insect and pest attack.

3.4 Raising of seedling

The seeding of rice were raised in wet bed methods. The seed bed selected for the experiment was open by hand spade on 26th April 2005. Seeds (95% germination) @ 5 kg ha^{-1} were soaked and incubated for 48 hrs. The seeds were sown on 5th May, 2005 in well prepared seed bed. During seedling growth no fertilizer was used. Proper water and pest management practices were followed whenever required.

3.5 Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator on the 10th May 2005, afterwards the land was ploughed and cross-ploughed several times under water saturated condition and puddled properly. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section (3.6).

3.6 Layout of the experiment

The experiment was laid out in a two factor Randomized Complete Block Design with three replications. The total number of plots was 48, each measuring 4m × 2.5m ($10m^2$). The treatment combinations of the experiment were assigned at random into 16 plots of each block. The distance maintained between two plots was 1 m and between blocks was 1.5 m. The layout of the experiment is presented in Figure 2.

3.7 Treatments

The experiment consists of 2 Factors i.e. vermicompost and fertilizer each having four levels. Details of factors and their combinations are presented below:

Factor A: Vermicompost

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

V_1 = 2 t ha^{-1} (Low vermicompost)

V_2 = 4 t ha^{-1} (Medium vermicompost)

V_3 = 6 t ha^{-1} (High vermicompost)

Factor B: Fertilizer

F_0 = 0 kg N ha^{-1} + 0 kg P_2O_5 ha^{-1} + 0 kg K_2O ha^{-1} (No NPK)

F_1 = 50 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} (Low NPK)

F_2 = 80 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} + 50 kg K_2O ha^{-1} (Medium NPK)

F_3 = 110 kg N ha^{-1} + 80 kg P_2O_5 ha^{-1} + 70 kg K_2O ha^{-1} (High NPK)

Treatment combination

V_0F_0 =Control (No vermicompost + No NPK)

V_0F_1 = (No vermicompost + Low NPK)

V_0F_2 = (No vermicompost + Medium NPK)

V_0F_3 = (No vermicompost + High NPK)

V_1F_0 = (Low vermicompost + No NPK)

V_1F_1 = (Low vermicompost + Low NPK)

V_1F_2 = (Low vermicompost + Medium NPK)

V_1F_3 = (Low vermicompost + High NPK)

V_2F_0 = (Medium vermicompost + No NPK)

V_2F_1 = (Medium vermicompost + Low NPK)

V_2F_2 = (Medium vermicompost + Medium NPK)

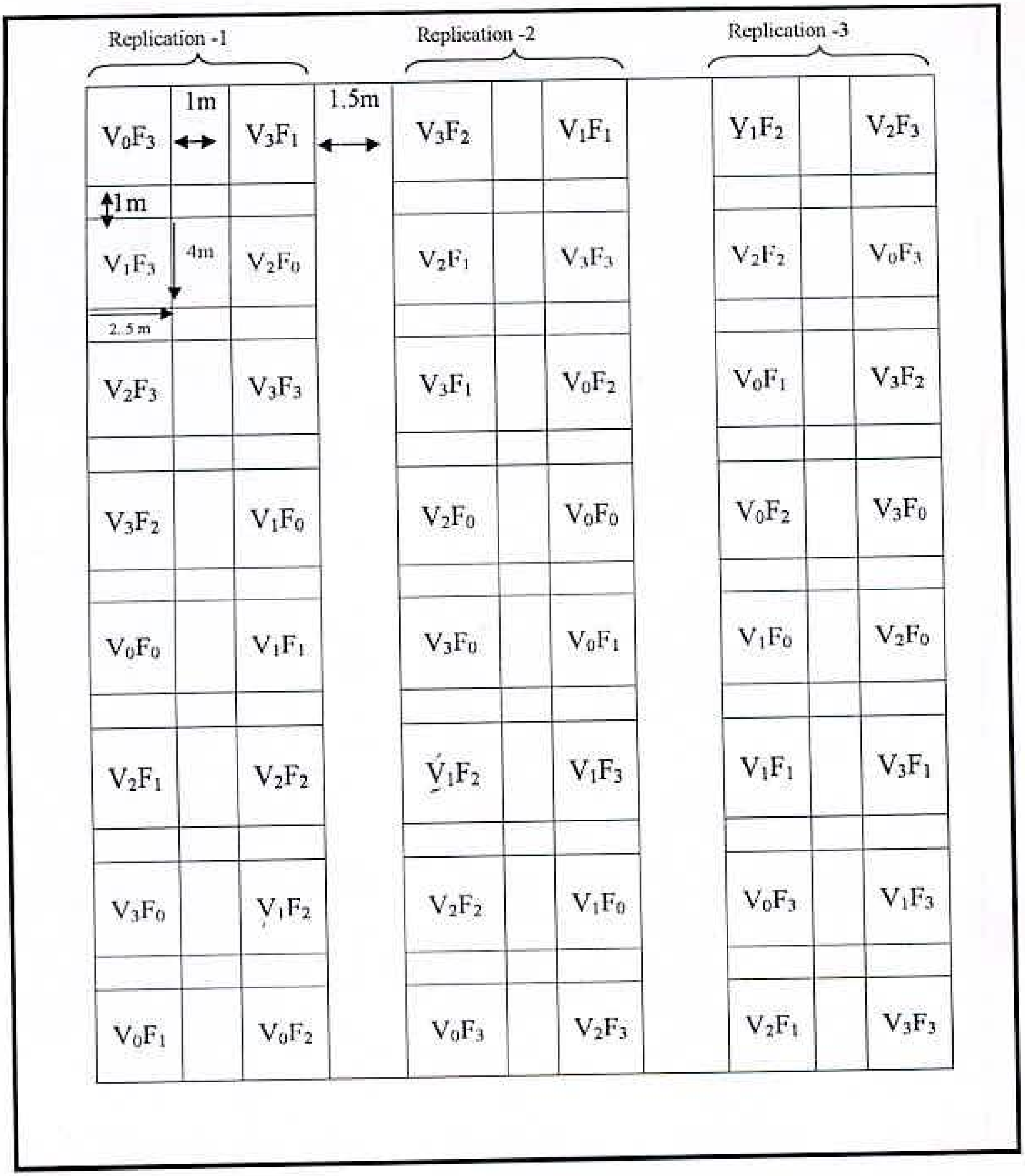
V_2F_3 = (Medium vermicompost + High NPK)

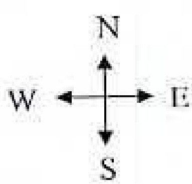
V_3F_0 = (High vermicompost + No NPK)

V_3F_1 = (High vermicompost + Low NPK)

V_3F_2 = (High vermicompost + Medium NPK)

V_3F_3 = (High vermicompost + High NPK)





Plot size: 4m x 2.5m (10m^2)
Plot to plot distance: 1m
Block to block distance: 1.5 m

Figure 2. Layout of the experimental field

3.8 Application of vermicompost and fertilizers

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..

3.9 Transplanting

Twenty one days old seedlings of BR–26 were transplanted on 26th May 2005 in T. Aus season. Three seedlings per hill were used following a line to line spacing of 20 cm and hill to hill spacing of 15 cm. After one week of transplanting all plots were checked for any missing hill which was filled up with extra seedlings whenever required.

3.10 Cultural and management practices

Various intercultural operations such as weeding and spraying of insecticides were accomplished whenever required to keep the plants healthy and the field weed free. The field was weeded out three times at 9, 20 and at 45 days after transplanting. The plants were attacked by borer insects which were removed by applying diazinon (60Ec) @ of 1.70 lit.ha^{-1}. Special care was taken to protect the crop from birds especially at the ripening stage of the crop.

3.11 Harvesting

The crop was harvested at maturity from $1m^2$ area of each plot on 18th August 2005. The harvested crop of each individual plot was bundled separately. Grain and straw yields were recorded plot wise and the yields were expressed in t ha^{-1}

3.12 Collection of samples

3.12.1 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. Post harvest soil samples were collected from each plot separately at 0-15 cm depth on 20th August 2005. The samples were air -dried, ground and sieved through a 2 mm (10 mesh) sieve and preserved for analysis.

3.12.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at the harvesting stage of the 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 the 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.

3.13 Collection of data

Data collection were done on the following parameters-

3.13.1 Plant height

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

3.13.2 Panicle length

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

3.13.3 Flag leaf length

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

3.13.4 No. of Grains per panicle

It was done after harvesting, at first number of grains per panicle were counted. Grains from 10 panicle were counted and averaged.

3.13.5 % of spikelet sterility

Sterile spikelet were counted after harvested panicles. Randomly ten panicles were selected and counted its sterile spikelets and then converted into percent.

3.13.6 Thousand seed weight

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

3.13.7 Grain yield

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

3.13.8 Straw yield

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

3.14 Chemical analysis of the plant, soil and vermicompost samples

3.14.1 Plant sample analysis

The plant samples collected at the harvesting stage of the crop were digested with conc. HNO_3 and $HClO_4$ mixture for the determination of P, K and S.

3.14.2. a Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4 : $CuSO_4.5H_2O$: Selenium powder in the ratio 100 : 10 : 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.14. 3. b Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.14.4. c Potassium

Potassium content in plant sample was determined by flame photometer.

3.14.5. d Sulphur

Sulphur content in the digests were determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049)

3.14.2 Soil sample analysis

3.14.2. a Organic carbon

Soil organic carbon was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973) from the soil samples collected before sowing and also after harvesting the crop.

3.14.2. b Organic matter

The organic matter content was determined by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950)

3.14.2. c Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Selenium powder in the ratio 100 :10 :1, respectively). Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.14.2. d Available Phosphorous

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 1949).

3.14.2. e Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate and the potassium content was determined by flame photometer.

3.14.2. f Available sulphur

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2$. H_2O (Fox *et al.*,1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.14.3 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, 0.6298% total N, 0.02249% available P, 0.07826% available K and 0.0313% available S.

3.14.4 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the differences among pairs of treatment means was estimated by the least significant difference (LSD) test at 5% and 1% level of probability and DMRT was calculated (Gomez and Gomez., 1984).

Chapter 4

Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The results on different growth characteristics, yield attributes, yield and nutrient concentrations in the plants and availability of different nutrients in the soil after harvest of rice are discussed in this chapter.

4.1 Effect of vermicompost and NPK on the growth parameters of rice.

4.1.1 Plant height

The effects of vermicompost and NPK fertilizers, alone and in combination, on the plant height of rice are presented (Table 2). Significant variation was observed on the plant height of rice when the field was incorporated with different doses of vermicompost. Among the different doses of vermicompost, V_2 (4 t ha^{-1}) showed the highest plant height (112.57 cm) which was statistically identical with the vermicompost doses of V_3 (6 t ha^{-1}) . On the other hand, the lowest plant height (102.24 cm) was observed in the V_0 treatment where no vermicompost was applied. Vermicompost might have increased the soil moisture content, soil porosity and other plant growth enhancing characters and for that reason increasing dose of vermicompost increased plant height. Similar result was reported by Gorlitz (1987). Agrawal *et al.* (2003) found that the increase in soil organic matter content through the application of FYM in wheat increased plant height.

Table 2. Effect of vermicompost on the growth contributing characters of rice

Vermicompost	Plant height (cm)	Panicle length(cm)	Flag leaf length (cm)
V_0	102.24b	21.74c	32.25d
V_1	103.42b	21.45 c	34.25c
V_2	**112.57a**	23.79b	**37.25a**
V_3	111.97a	**26.52a**	35.25 b
Level of Significance	0.01	0.05	0.01

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

Table 3. Effect of NPK fertilizers on the growth contributing characters of rice

NPK Fertilizer	Plant height (cm)	Panicle length (cm)	Flag leaf length (cm)
F_0	101.16d	22.44b	34.00c
F_1	105.23c	23.26a	32.57d
F_2	110.15b	23.85a	36.50b
F_3	**113.57a**	**23.98a**	**38.75a**
Level of Significance	0.01	0.01	0.01

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

Rice plants showed significant variation in respect of plant height when fertilizers in different doses were applied (Table 3). Among the different fertilizer doses, F_3 (High NPK) showed the highest plant height (113.57cm). On the contrary, the lowest plant height (101.16 cm) was observed in F_0 treatment where no fertilizer was applied (Table 3). Song *et al.* (2001) found that application of fertilizer NPK increased the height of wheat plant compared with control treatment.

Combined application of different doses of vermicompost and fertilizer had significant effect on the plant height of rice (Table 4). The lowest plant height (96.67 cm) was observed in the control treatmen M_0F_0 (No vermicompost and No NPK). On the other hand, the highest plant height (119.30 cm) was recorded with V_3F_2 (High vermicompost + Medium NPK). Similar result was reported by Song *et al.* (2001). They found that application of fertilizer NPK combined with various sources of OM increased the height of wheat plant compared with the control treatment.

It is evident from the data that vermicompost at the high rate along with medium dose of NPK resulted the highest plant height of rice.

Table 4. Effect of vermicompost and NPK fertilizers on the growth contributing characters of rice

Vermicompost × NPK Fertilizer	Plant height (cm)	Panicle length (cm)	Flag leaf length (cm)
V_0F_0	**96.67 e**	**20.50 g**	**28.00 h**
V_0F_1	99.00 e	21.50 fg	29.00 gh
V_0F_2	104.00 cde	21.90 ef	34.00 ef
V_0F_3	109.30 abcd	23.07 de	38.00 bcd
V_1F_0	98.67 de	21.00 fg	39.00 bc
V_1F_1	100.00 de	21.23 fg	30.00 gh
V_1F_2	102.30cde	22.17 ef	32.00 fg
V_1F_3	112.70abc	21.40 cd	36.00 bc
V_2F_0	105.00bcde	22.93 de	34.00 ef
V_2F_1	113.00abc	24.13 cd	37.00 cde
V_2F_2	115.30 ab	22.93 de	38.00 bcd
V_2F_3	117.00 a	25.17 bc	40.00 abc
V_3F_0	104.30 cde	25.33 bc	35.00 def
V_3F_1	109.3 abcd	26.17 b	35.00 def
V_3F_2	**119.00 a**	**28.40 a**	**42.00 a**
V_3F_3	115.30 ab	26.27 b	41.00 ab
Level of Significance	0.01	0.01	0.01

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

4.1.2. Panicle length(cm)

The effects of vermicompost and NPK fertilizers alone and in combination of two sources on the panicle height of rice are presented (Table 2). Significant variation was observed on the panicle height of rice when the field was incorporated with different doses of vermicompost.

Among the different doses of vermicompost, V_3 (6 t ha^{-1}) showed the highest panicle height (26.52 cm). On the other hand, the lowest panicle height (21.45 cm) was observed in the V_1 (2 t ha^{-1}) treatment where low doses of vermicompost was applied. Vermicompost might have increased the soil moisture content, soil porosity and other plant growth enhancing characters and for that reason increasing dose of vermicompost increased plant and the panicle height as well.

Rice plants showed significant variation in respect of panicle height when fertilizers in different doses were applied (Table 3). Among the different fertilizer doses, F_3 (High NPK) showed the highest panicle height (23.98 cm), which was statistically identical (23.86) and(23.26) with the fertilizer doses of F_2(Medium NPK) and F_1(Low of NPK).. On the contrary, the lowest panicle height (22.44 cm) was observed in F_0 treatment where no fertilizer was applied (Table 3).

Combined application of different doses of vermicompost and fertilizer had significant effect on the panicle height of rice (Table 4). The lowest panicle height (20.50 cm) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPK). On the other hand, the highest panicle height (28.40 cm) was recorded with V_3F_2 (High vermicompost + Medium NPK). It is evident from the data that vermicompost at the high rate along with medium dose of NPK resulted the highest panicle height of rice.

4.1.3. Flag leaf length (cm)

The effects of vermicompost and NPK fertilizers alone and in combination of two sources on the flag leaf length of rice are presented (Table 2). Significant variation was observed on the flag leaf length of rice when the field was incorporated with different doses of vermicompost. Among the different doses of vermicompost, V_2 (4 t ha^{-1}) showed the highest flag leaf length

(37.25 cm). On the other hand, the lowest flag leaf length (32.25 cm) was observed in the V_0 treatment where no vermicompost was applied.

Rice plants showed significant variation in respect of flag leaf length when fertilizers in different doses were applied (Table 3). Among the different fertilizer doses, F_3 (High NPK) showed the highest flag leaf length (38.75 cm). On the contrary, the lowest flag leaf length height (32.57 cm) was observed in F_1 (2 t ha-^{1}) treatment where low doses of fertilizer was applied (Table 3).

Combined application of different doses of vermicompost and fertilizer had significant effect on the flag leaf length of rice (Table 4). The lowest flag leaf length (28.00 cm) was observed in the control treatment (No vermicompost and No NPK). On the other hand, the highest flag leaf length (42.00 cm) was recorded with V_3F_2 (High vermicompost + Medium NPK), which was statistically similar with V_3F_3 treatment. It is evident from the data that vermicompost at the high rate along with the medium and high dose of NPK resulted the highest flag leaf length of rice.

4.2. Effect of vermicompost and NPK on the yield parameters of rice.

4.2.1. Weight of 1000 grain

Significant variation was observed in the weight of 1000 seeds of when different doses of vermicompost were applied (Table 5). The highest 1000 seed weight (22.72 g) was recorded in V_0 (No vermicompost), and the lowest 1000 seed weight (22.52 g) was recorded in the V_2 (4 t ha-^{1}) treatment where low vermicompost was applied. Similar result was reported by Shafiuddin Kaisar Zaman (2002). He found that no vermicompost + no NPKS treatment resulted in the highest 1000 seed weight.

Different doses of chemical fertilizers showed significant variations in respect of weight of 1000 grain (Table 6). Among the different doses of fertilizers, F_2 (Medium NPK) showed the lowest weight of 1000 seeds (22.50 g), which was statistically identical with the fertilizer doses of F_2 (Medium NPK) and F_3 (High NPK). On the contrary, the highest weight of 1000 seeds (22.84 g) was observed with F_0, where no fertilizer was applied. Similar result was reported by Shafiuddin Kaisar Zaman (2002).

The combined effect of different doses of vermicompost and fertilizer on the weight of 1000 seeds of rice was significant0(Table 7). But the highest weight of 1000 seed (23.30g) was recorded with the treatment combination of V_0F_0 (No vermicompost + No NPK). On the other hand, the lowest weight of 1000 seed (22.17 g) was found in V_2F_2 treatment (Medium vermicompost and Medium NPK).

4.2.2 Grain yield of rice

The grain yield as affected by different doses of vermicompost was not statistically significant (Table 5). Among the different doses of vermicompost the highest grain yield (4.27 t ha^{-1}) was observed in V_3 (6 t ha^{-1}). The lowest grain yield (3.31 t ha^{-1}) was recorded in the V_0 treatment where no vermicompost was applied. Probably vermicompost supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest yield of rice. Ranwa and Sing (1999) reported that the application of vermicompost (7.5 t ha^{-1}) improved grain yield of wheat. Fouda (1989) stated that grain yield of wheat were increased with the increasing rate of compost application.

Application of fertilizers at different treatment doses showed a significant variation on the of grain yield of rice in Table 6. Among the different doses, F_2 (Medium NPK) showed the highest grain yield (4.05 t ha^{-1}). On the other hand, the lowest grain yield (3.27 t ha^{-1}) was recorded with F_0 treatment, where no fertilizer was applied. Similar results were reported by Kadar and Csatho (1987) and Dang *et al.* (1988). Optimum fertilizer doses increase the vegetative growth and development of wheat that lead to the highest grain yield. Patel *et al.* (1995) showed that grain yield of wheat was increased with increasing rates of NPK fertilizer and the highest yield was obtained with 120: 60: 40 kg NPK ha^{-1}, respectively.

Combined effects of different doses of vermicompost and fertilizers on grain yield showed a statistically significant variation (Table 7). The highest grain yield (4.80 t ha^{-1}) was recorded in the treatment combination of V_3F_2 (High vermicompost + Medium NPK). On the other hand, the lowest grain yield (3.03 t ha^{-1}) was found in V_0F_0 (No vermicompost + No NPK). It is observed that the application of fertilizer NPK combined with OM not only make good use of resources, but also enhance rice yield. Similar result was obtained by Deshmukh *et al.* (2005). They found that the application of recommended dose of fertilizer NPK combined with FYM recorded the height grain yield of soybean. Similar result was obtained by Song *et al.* (2001). They found that the application of NPK fertilizers combined with OM enhanced biomass production and the grain yield of wheat. Vasanti and Kumaraswamy (2000) reported that vermicompost at 5 t ha^{-1}would be sufficient for rice crop when applied with recommended levels of N, P and K

Table 5. Effect of vermicompost on the yield contributing characters of rice

Vermicompost	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0	**22.72**	3.31d	5.64d
V_1	22.60	3.74b	6.12b
V_2	22.52	3.65b	6.35b
V_3	22.60	**4.27a**	**7.12a**
Level of Significance	NS	0.05	0.01

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

Table 6. Effect of NPK fertilizers on the yield contributing characters of rice

Fertilizer	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
F_0	**22.84a**	3.27c	5.61c
F_1	22.54b	3.64b	6.09b
F_2	22.50b	**4.05a**	6.76a
F_3	22.55b	4.02a	**6.77a**
Level of Significance	0.05	0.01	0.01

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

Table 7. Combined effect of vermicompost and NPK fertilizers on the yield contributing characters of rice

Vermicompost × NPK Fertilizer	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0F_0	**23.30 a**	**3.03 i**	**5.25 f**
V_0F_1	22.33 bc	3.20 hi	5.50 ef
V_0F_2	22.70 bc	3.60 efgh	6.00 d
V_0F_3	22.53 bc	3.40 ghi	5.80 de
V_1F_0	22.73 bc	3.30 ghi	5.60 def
V_1F_1	22.60 bc	3.45 fghi	5.80 de
V_1F_2	22.53 bc	4.00 bcde	6.50 c
V_1F_3	22.53 bc	4.20 bcd	6.60 c
V_2F_0	22.73 bc	3.35 ghi	5.60 def
V_2F_1	22.43 bc	3.50 efgjhi	5.80 de
V_2F_2	**22.17 c**	3.80 defg	6.80 c
V_2F_3	22.73 bc	3.97 cdef	7.20 b
V_3F_0	22.60 bc	3.40 ghi	6.00 d
V_3F_1	22.80 ab	4.40 abc	7.25 b
V_3F_2	22.60 bc	**4.80 a**	**7.75 a**
V_3F_3	22.40 bc	4.50 ab	7.50 ab
Level of Significance	0.01	0.01	0.01

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

4.2.3 Straw yield

Significant variation in straw yield of rice was observed with different doses of vermicompost (Table 5) . Among the different doses of vermicompost V_3 (6 t ha^{-1}) showed the highest straw yield (7.12 t ha^{-1}). On the other hand, the lowest straw yield (5.64 t ha^{-1}) was observed in the V_0 treatment, where no vermicompost was applied. Bangar *et al.* (1990) reported that compost increased straw yield significantly.

Straw yield showed significant variation when different doses of fertilizers were applied (Table 6). Among the different fertilizer doses, F_3 (High NPK) showed the highest straw yield (6.77 t ha^{-1}). The lowest straw yield (5.61 t ha^{-1}) was observed with F_0 treatment, where no fertilizer was applied. Similar result was obtained by Starling *et al.* (1998).

Combined effect of different doses of vermicompost and fertilizers showed a statistically significant effect on the straw yield of rice in Table 7 .The lowest straw yield (5.25 t ha^{-1}) was observed in the control treatment (No vermicompost and No NPK). On the other hand, the highest straw yield (7.75 t ha^{-1}) was recorded with V_3F_2 (High vermicompost + Medium NPK),.Song *et al.* (2001) found similar results with the application of fertilizer NPK combined with OM which enhanced biomass and grain yield of wheat.

4.2.4 Number of grains/ panicle

Significant variation was observed in the number of grains/panicle of rice when different doses of vermicompost were applied (Table 8). The highest number of grains/panicle (100.07) was recorded in V_3 (6 t ha^{-1}), and the lowest number of grains/panicle (66.42) was recorded in the V_0 treatment where no vermicompost was applied. The increased number of grains/panicle may be due to favorable effects of vermicompost on the vegetative growth and accumulation of materials that helped proper growth and development of the rice grain.

Table 8. Effect of vermicompost on the yield contributing characters of rice

Vermicompost	No.of grains/panicle	% of spikelet sterility
V_0	66.42c	29.25b
V_1	66.84c	29.25b
V_2	80.17b	**32.50a**
V_3	**100.07a**	31.75a
Level of Significance	0.01	0.01

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

Table 9. Effect of NPK fertilizers on the yield contributing characters of rice

NPK fertilizer	No. of grains /panicle	% of spikelet sterility
F_0	73.17e	29.25c
F_1	74.17d	31.00a
F_2	82.91b	31.00 a
F_3	**83.24a**	**31.50a**
Level of Significance	0.01	0.01

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

Table 10. Combined effect of vermicompost and NPK fertilizers on the yield contributing characters of rice

Vermicompost × NPK Fertilizer	No of grains/panicle	% of spikelet sterility
V_0F_0	**59.33 i**	**26.00 e**
V_0F_1	63.67 hi	30.00 ab
V_0F_2	69.33 fgh	31.00 ab
V_0F_3	73.33 fg	30.00 ab
V_1F_0	63.67 hi	26.00 c
V_1F_1	64.67 hi	30.00 ab
V_1F_2	71.33 fgh	31.00 ab
V_1F_3	67.67 gh	30.00 ab
V_2F_0	76.33 ef	33.00 ab
V_2F_1	72.00 ef	**34.00 a**
V_2F_2	82.67 de	30.00 ab
V_2F_3	89.67 cd	33.00 ab
V_3F_0	93.33 c	32.00 ab
V_3F_1	96.33 bc	30.00 ab
V_3F_2	**108.3 a**	32.00 ab
V_3F_3	102.3 ab	33.00 ab
Level of Significance	0.01	0.01

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

Different doses of chemical fertilizers showed significant variations in respect of number of grains/penicle (Table 9). Among the different doses of fertilizers, F_3 (High NPK) showed the highest number of grains/panicle(83.24). On the contrary, the lowest number of grains/panice (73.17) was observed with F_0.

The combined effect of different doses of vermicompost and fertilizers on number of grains/panicle of rice was significant(Table10). The highest number of grains/panicle (108.30) was recorded with the treatment combination of V_3F_2 (High vermicompost +

Medium NPK). On the other hand, the lowest number of grains/panicle (59.33) was found in M_0F_0 treatment (No vermicompost and No NPK).

4.2.5 % of spikelet sterility

Significant variation was observed in the % of spikelet sterility of rice when different doses of vermicompost were applied (Table 8). The highest % of spikelet sterility (32.50) was recorded in V_2 (4 t ha^{-1}) which was statistically identical (31.75) with the V_3(High vermicompost) and the lowest % of spikelet sterility (29.25) was recorded in the V_0 treatment where no vermicompost was applied which was statistically identical (26.00) with the V_1 (Low vermicompost). The increased % of spikelet sterility due to increased dose of vermicompost may be due to favorable effects of vermicompost on the vegetative growth and accumulation of materials that helped proper growth and development of the rice panicles.

Different doses of chemical fertilizers showed significant variations in respect of % of spikelet sterility (Table 9). Among the different doses of fertilizers, F_3 (High NPK) showed the highest % of spikelet sterility(31.50), which was statistically identical (31.00) with the fertilizer doses of F_2(Medium NPK) and F_1(Low of NPK). On the contrary, the lowest % of spikelet sterility (29.25) was observed with F_0.

The combined effect of different doses of vermicompost and fertilizers on % of spikelet sterility of rice was statistically significant in Table 10. The highest % of spikelet sterility (34.00) was recorded with the treatment combination of V_2F_1 (Medium vermicompost + Low NPK) which showed statistically similar results with all the treatment combinations except V_0F_0 and V_1F_0. On the other hand, the lowest % of spikelet sterility (26.00) was found in V_0F_0 treatment (No vermicompost and No NPK).

4.3 Effect of vermicompost and NPK fertilizers on the nutrient concentrations in rice plant

4.3.1 Nitrogen content

A statistically significant variation was observed in nitrogen concentration in rice plant after harvest when different doses of vermicompost were applied (Table 11). The effect of different doses of vermicompost revealed that the highest nitrogen concentration (0.92 %) was recorded in V_3 (6 t ha^{-1}) . The lowest nitrogen concentration (0.67 %) was recorded in the V_0 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 the crop over no vermicompost treatment.

Application of different doses of chemical fertilizers showed a statistically significant variation in respect of nitrogen concentration in rice plant after harvest (Table 12). Among the different fertilizer doses, F_3 (High NPK) showed the highest nitrogen concentration (1.34%) and the lowest nitrogen concentration (0.58%) was recorded in the F_0 where none of the fertilizers was applied. This may be due to more NPK application which helped to enhance nitrogen content in rice plant.

The effect of combined applications of different doses of vermicompost and fertilizers resulted significant variations in nitrogen content in plant at the harvest of the rice (Table 13). The highest nitrogen concentration (1.54%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest nitrogen concentration (0.49%) was found in V_0F_0 (No vermicompost +No NPK) treatment combination. The highest rates of application of vermicompost and NPK showed the highest nitrogen content in rice straw.

Table 11. Effect of vermicompost on the NPKS concentrations in rice plant

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	0.67 c	0.63 c	1.85c	0.18b
V_1	0.88 b	0.65 b	1.86b	0.18b
V_2	0.84 b	**0.68 a**	**1.87a**	**0.19a**
V_3	**0.92 a**	0.63 c	1.80d	0.18b
Level of Significance	0.05	0.05	0.05	0.01

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

Table 12. Effect of NPK fertilizers on the NPKS concentrations in rice plant

Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	0.58d	0.37d	1.53d	0.055d
F_1	0.66c	0.63c	1.78c	0.215 b
F_2	0.73 b	0.73b	1.97b	0.222b
F_3	**1.34a**	**0.83 a**	**2.10 a**	**0.263a**
Level of Significance	0.01	0.01	0.01	0.05

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

4.3.2 Phosphorous content

Significant variation was recorded with phosphorous concentration in rice after harvest when vermicompost was applied at different doses (Table 11). Considering the effect of different doses of vermicompost the highest phosphorous concentration (0.68%) was recorded in V_2 (4 t ha^{-1}).The lowest phosphorous concentration (0.63%) was recorded in the V_3 (6 t ha^{-1}) and V_0 treatment .

Table 13. Combined effect of vermicompost and NPK fertilizers on the NPKS concentrations in rice plant

Vermicompost × NPK Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	**0.49 h**	0.43 h	**1.40 g**	0.056 g
V_0F_1	0.61 f	0.59 g	1.91 cde	0.207 def
V_0F_2	0.72 de	0.69 de	2.01 bc	0.220 cde
V_0F_3	0.84 c	0.80 b	2.08 b	0.250 b
V_1F_0	0.59 fg	0.44h	1.45 g	0.060 g
V_1F_1	0.72 de	0. 61 fg	1.88 e	0.193 f
V_1F_2	0.72 de	0.72 d	2.01 bc	0.223 cd
V_1F_3	1.50 ab	0.83 ab	2.08 b	0.253 b
V_2F_0	0.63 f	0.41 h	1.67 f	**0.050 g**
V_2F_1	0.54 g	0.65 ef	1.86 e	0.203 ef
V_2F_2	0.70 e	0.78 bc	1.96 bcd	0.223 cd
V_2F_3	1.48 b	**0.87 a**	1.99 bcd	0.273 a
V_3F_0	0.59 fg	**0.32 i**	1.60 f	0.055 g
V_3F_1	0.76 d	0.66 ef	1.46 g	0.217 cde
V_3F_2	0.77 d	0.74 cd	1.89 de	0.227 c
V_3F_3	**1.54 a**	0.81 b	**2.23 a**	**0.277 a**
Level of Significance	0.05	0.01	0.05	0.01

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

Different doses of chemical fertilizers resulted a significant variation in phosphorous concentration in rice plant at the harvest (Table 12). Among the different fertilizer doses, F_3 (High NPK) showed the highest phosphorous concentratin (0.83%) in plant, and the lowest phosphorous concentration (0.37%) was recorded in the F_0 treatment. It was observed that phosphorous content increased with higher rates of application of NPK.

The effect of different doses of vermicompost and fertilizers at various combinations on the phosphorous concentration in rice plant was statistically significant (Table 13). The highest phosphorous concentration (0.87%) was recorded in the treatment combination of V_2F_3 (Medium vermicompost + High NPK). On the other hand, the lowest phosphorous concentration (0.41%) was found in V_2F_0 (Medium vermicompost + No NPK) treatment combination. The highest result might be due to optimum rate of application of vermicompost and higher doses of NPK in V_2F_3 treatment.

4.3.3 Potassium content

Statistically significant variation was not recorded in potassium concentration in rice plant after harvest when the effects of different doses of vermicompost were compared (Table 11). Considering the effect of different doses of vermicompost, the highest potassium concentration (1.87%) was recorded in V_2 (4 t ha^{-1}), and the lowest potassium concentration (1.80%) was recorded in the V_3 (6 t ha^{-1}) treatment of vermicompost .

Application of different doses of chemical fertilizers resulted a significant variation in potassium concentration in rice plant after harvest (Table 12). Among the different combinations of fertilizer, F_3 (High NPK) showed the highest potassium concentration (2.10%) in rice plant. On the other hand, the lowest potassium concentration (1.53%) was recorded with F_0 where no fertilizer was applied.

Combined application of vermicompost and fertilizers at different levels showed significant effect on potassium concentration in rice plant after harvest (Table 13). The highest potassium concentration (2.23%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest potassium concentration (1.40%) was found in V_0F_0 (No vermicompost + No NPK) .

4. 3.4 Sulphur content

Statistically significant variation was recorded in sulphur concentration in rice plant after harvest when the effects of different doses of vermicompost were compared (Table 11). Considering the effect of different doses of vermicompost, the highest sulphur concentration (0.19%) was recorded in V_2 (4 t ha^{-1}), and the lowest sulphur concentration (0.18%) was recorded in the V_0 (No vermicompost) treatment, which was statistically identical V_3 (6 t ha^{-1}),and V_1 (2 t ha^{-1}) respectively .

Significant variation was observed with the application of different doses of chemical fertilizers with respect of sulphur concentration in rice plant (Table 12). Fertilizer dose, F_3 (High NPK) yielded highest sulphur concentration (0.26%) in plant and the lowest sulphur concentration (0.055%) was recorded in F_0 treatment where no fertilizer was applied.

Combined effect the different doses of vermicompost and fertilizers on the sulphur concentration in rice plant showed statistically significant difference (Table 13). The highest sulphur concentration (0.277%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK) which was statistically identical with V_2F_3 (Medium vermicompost + High NPK). On the other hand, the lowest sulphur concentration (0.050%) was found in with V_2F_0 (Medium vermicompost + No NPK) treatment combination.

4.4 Effect of vermicompost and NPK fertilizers on the uptake of nutrients by rice plant

4.4.1 Nitrogen uptake

The effect of vermicompost on nitrogen uptake by rice plant showed significant variations (Figure 3 and Appendix Table 1). Nitrogen uptake was maximum in the treatment V_3 (High vermicompost) having (105.83 kg ha^{-1}). The minimum nitrogen uptake by rice (60.09 kg ha^{-1}) was recorded with control. Baron *et al.* (1995) found that the addition of organic manure has a positive influence on the N uptake by wheat plants.

Application of NPK at different doses significantly influenced nitrogen uptake by rice plants (Figure 4 and Appendix Table 2). Nitrogen uptake ranged from(147.42 kg ha^{-1})with highest in the treatment F_3 (High NPK) to the lowest of (50.77 kg ha^{-1}) in the control treatment (NO NPK).

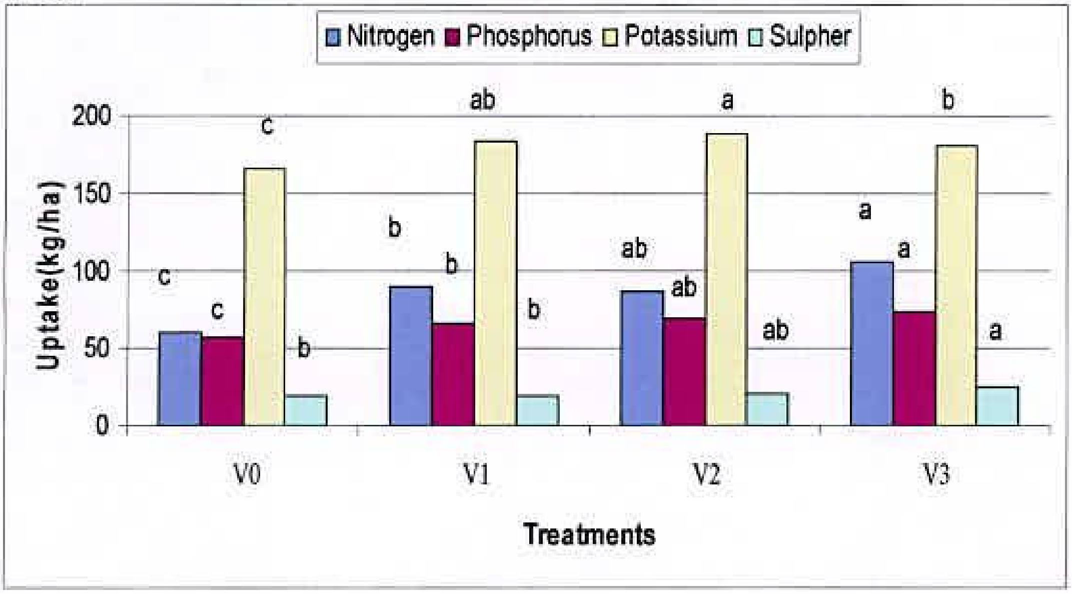


Figure 3. Effect of vermicompost on NPKS uptake by rice plant

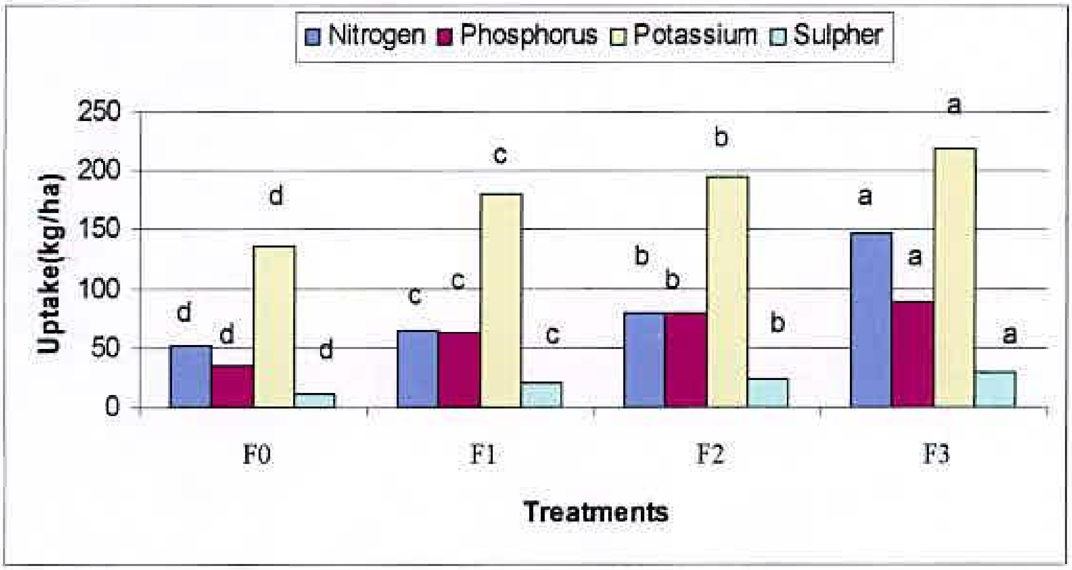


Figure 4. Effect of NPK fertilizers on NPKS uptake by rice plant

The combined effect of different doses of vermicompost and fertilizers on nitrogen uptake showed statistically significant variation (Figure 5 and Appendix Table 3). The highest N uptake (184.8 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK) .On the other hand , the lowest nitrogen uptake (40.58 kg ha^{-1}) was recorded in the control treatment (V_0F_0) where no vermicompost and no NPK was applied.

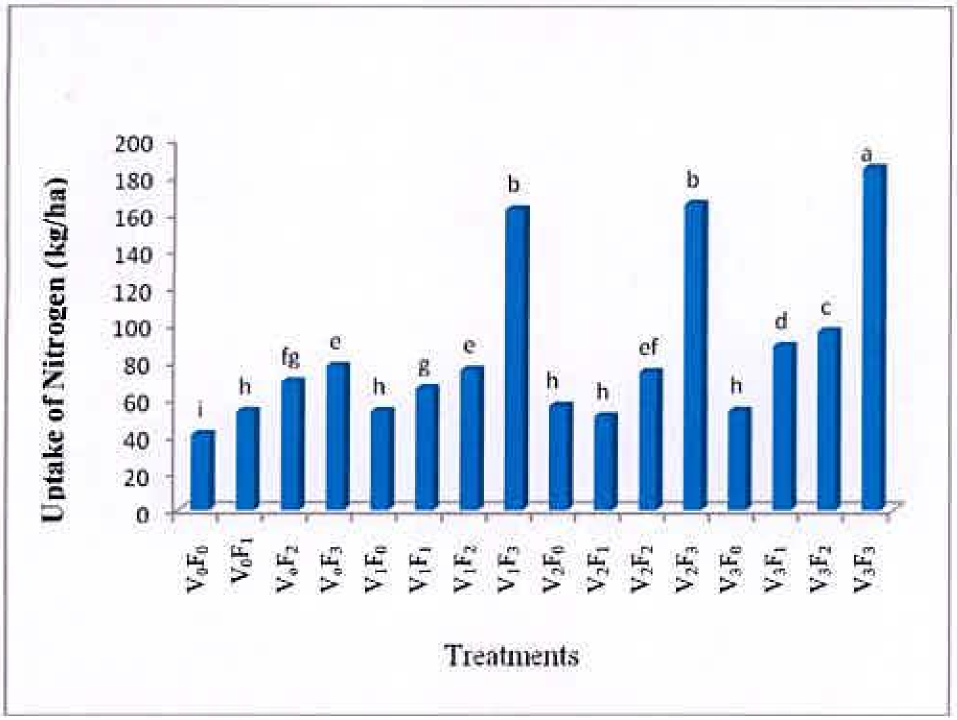


Figure 5. Combined effect of vermicompost and NPK fertilizers on nitrogen uptake by rice plant

4.4.2 Phosphorus uptake

Phosphorus uptake by rice plant was significantly influenced due to the addition of vermicompost (Figure 3 and Appendix Table 1). Phosphorus uptake ranged from the lowest of 56.83 (F_0) to the height of 74.10 kg ha^{-1} (F_3) .

Phosphorus uptake by rice plant was significantly influenced due to the application of NPK (Figure 4 and Appendix Table 2). Phosphorus uptake by plant ranged from 35.49 to 89.13 kg ha^{-1} with maximum in treatment, F_3 (High NPK) and minimum in F_0 treatment.

Combined effect of different doses of vermicompost and fertilizers on phosphorus uptake by rice showed statistically significant variation (Figure 6 and Appendix Table 3). The highest P uptake (97.07 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK), which was statistically identical with V_2F_3 (Medium vermicompost + High NPK) and the lowest uptake (35.46 kg ha^{-1}) was recorded in the V_0F_0 (No vermicompost + No NPK) treatment.

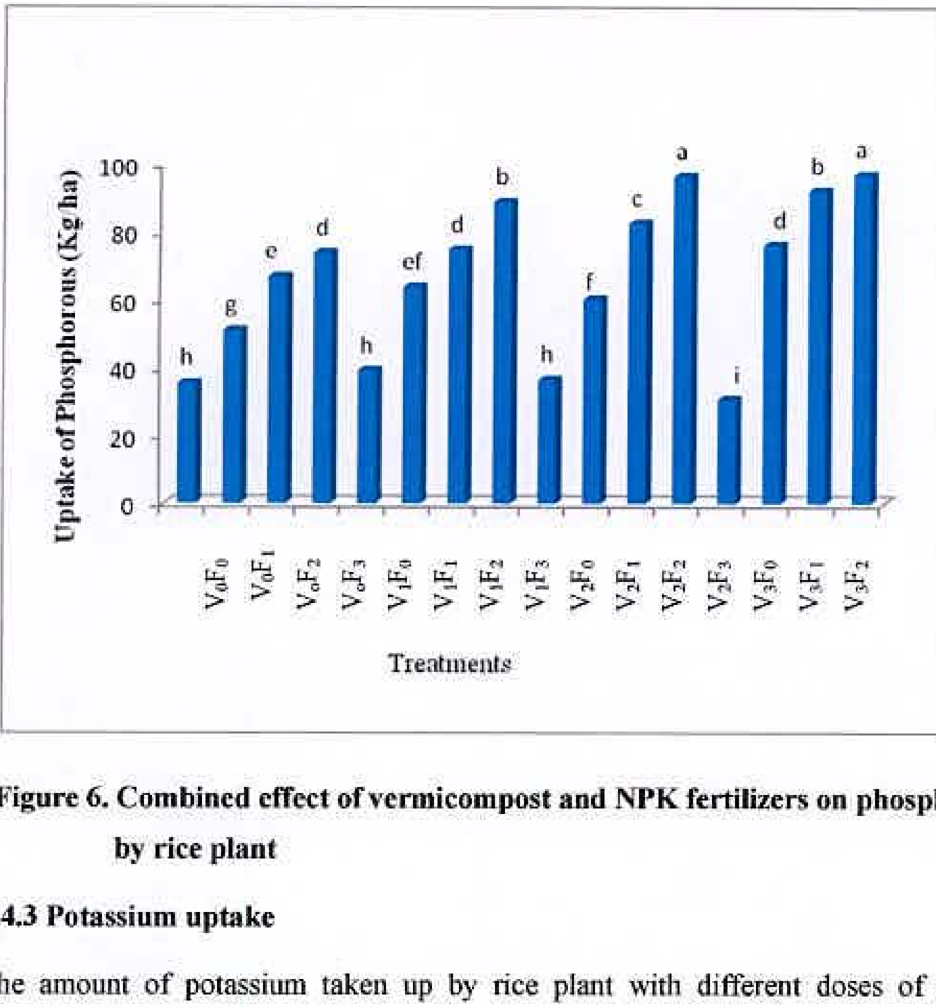


Figure 6. Combined effect of vermicompost and NPK fertilizers on phosphorus uptake by rice plant

4.4.3 Potassium uptake

The amount of potassium taken up by rice plant with different doses of vermicompost resulted significantly higher values over the control (Figure 3 and Appendix Table 1). Potassium uptake by rice plant was maximum (187.90 kg ha^{-1}) in the treatment V_2 (Medium vermicompost), and minimum (166.68 kg ha^{-1}) in the control. It is evident that vermicompost supplied more potassium and as a consequence its uptake was higher with the higher doses.

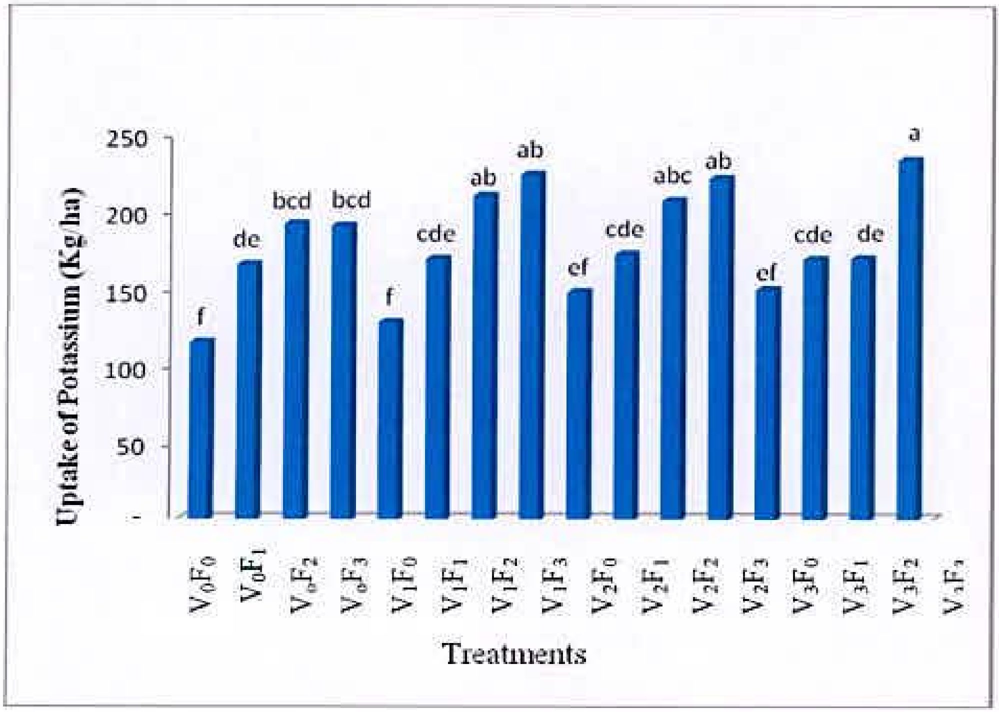


Figure 7. Combined effect of vermicompost and NPK fertilizers on ptassium uptake by rice plant

Application of different doses of NPK fertilizers significantly influenced potassium uptake by rice. Potassium uptake ranged from 135.98 to 218.08 kg ha^{-1} (Figure 4 and Appendix Table 2). The highest potassium uptake (218.08 kg ha^{-1}) was recorded with the treatment, F_3 (High NPK). The lowest (135.98 kg ha^{-1}) in control (F_0) treatment.

The effect of combined application of different doses of vermicompost and fertilizers on potassium uptake by rice showed statistically significant variation (Figure 7 and Appendix Table 3). The highest uptake (234.1 Kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand , the lowest uptake (116.0 Kg ha^{-1}) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPK). It might be due to the fact that vermicompost and NPK combined application showed positive effect on potassium uptake by rice.

4.4.4 Sulphur uptake

Sulphur uptake by rice plant showed highly significant influence due to the application of vermicompost (Figure 3 and Appendix Table 1). Sulphur uptake ranged from 18.44 to 24.75 kg ha^{-1}. The highest Sulphur uptake (24.75 kg ha^{-1}) was recorded with the treatment, V_3 (High vermicompost), and minimum (18.44 kg ha^{-1}) in the control treatment.

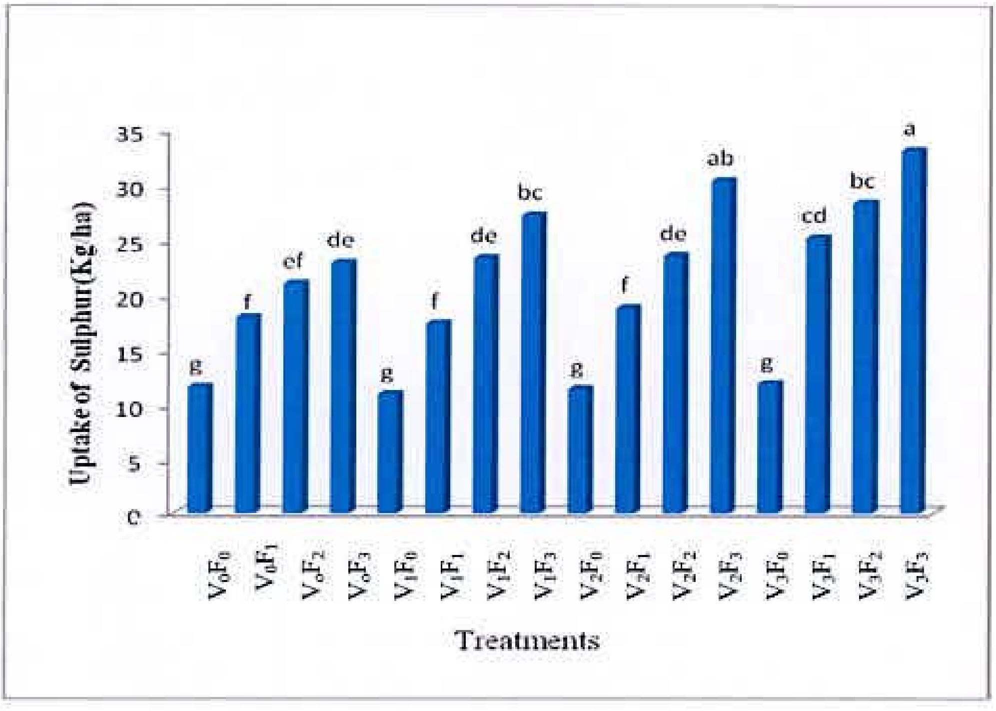


Figure 8. Combined effect of vermicompost and NPK fertilizers on sulphur uptake by rice plant

Sulphur uptake by rice was significantly influenced due to the application of different doses of NPK fertilizers (Figure 4 and Appendix Table 2). The maximum value (28.51 Kg ha^{-1})

was found in the treatment, F_3 (High NPK) the lowest value (11.52 kg ha^{-1}) was recorded in F_0 treatment where no NPK fertilizers were applied.

Combined applications of different doses of vermicompost and fertilizers showed significant variation on sulphur uptake by rice (Figure 8 and Appendix Table 3). The highest S uptake (33.24 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest uptake (11.01 kg ha^{-1}) was recorded in the treatment combination, V_1F_0 where low vermicompost and no fertilizers were added.

4.5 Effect of vermicompost and NPK fertilizers application on the nutrient status of soil after harvest

4.5.1 Organic matter content of soil

A significant variation was observed on the content of OM after harvest where vermicompost was incorporated in soil (Table14). Among the different doses of vermicompost, V_3 (6 t ha^{-1}) treatment showed the highest OM content (1.65%) after the harvest of crop. On the other hand, the lowest OM content (1.24%) was observed in the V_0 treatment where no vermicompost was applied. Vermicompost added more organic matter in the soil and as a consequence the residual amount of organic matter showed higher values with the addition of higher amount of vermicompost.

Table 14. Effect of vermicompost on the OM, total N, available P, exchangeable K, and available S contents in the soil after rice harvest.

Vermicompost	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)
V_0	1.24d	0.072c	**0.0031a**	0.0010d	0.0018b
V_1	1.41c	**0.078a**	0.0016c	**0.0013a**	0.0017c
V_2	1.50 b	0.039e	0.0017b	0.0012b	0.0018b
V_3	**1.65 a**	0.075 b	0.0016c	0.0011c	**0.0020a**
Level of Significance	0.01	0.01	0.01	0.01	0.01

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

A significant variation was observed on the content of OM after harvest where the fertilizers was applied in soil (Table 15). Among the different doses of fertilizers F_2 (Medium NPK) treatment showed the highest OM content (1.52%) after the harvest of crop. On the other hand, the lowest OM content (1.35 %) was observed in the F_0 treatment where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizers showed a significant variation on the content of OM after harvest where the vermicompost and fertilizer was applied in soil (Table 16). Among the different doses of vermicompost and fertilizer V_3F_1 (High vermicompost + Low NPK) treatment showed the highest OM content (1.77%) after the harvest of crop, which was statistically identical (1.75%) with the combined doses of V_3 F_2 (High vermicompost +Medium NPK). On the other hand, the lowest OM content (1.07 %) was observed in the V_0F_0 (No vermicompost + No NPK) treatment.

Table 15. Effect of NPK fertilizers on the OM, total N, available P, exchangeable K and available S content in the soil after rice harvest

NPK Fertilizer	OM (%)	Total N (%)	Available P (%)	Available K(%)	Available S (%)
F_0	1.35 d	0.061 d	**0.0027 a**	0.00081d	0.0014 d
F_1	1.45 c	0.068 c	0.00 14 d	0.00094 c	0.0017 c
F_2	**1.52 a**	0.073 b	0.0019 c	0.0013 b	0.0021 b
F_3	1.48 b	**0.097 a**	0.0021 b	**0.0015 a**	**0.0024 a**
Level of Significance	0.01	0.01	0.01	0.01	0.01

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

4.5.2 Nitrogen content of soil

Significant variation was recorded on the nitrogen content of rice field after harvest of the crop when the field was treated with different doses of vermicompost (Table 14). Among the different doses of vermicompost, V_1 (2 t ha^{-1}) treatment showed the highest N content (0.078%) and the lowest N content (0.039%) was observed in the V_2 (4 t ha^{-1}) treatment where medium doses vermicompost was applied. This was due to the fact that vermicompost added N in soil and reduced the loss of nitrogen and conserved more nitrogen in soil. Bangar *et al.* (1990) found that compost enriched the N content of soil.

A significant variation was recorded in the N content of soil after harvest of the rice crop when different fertilizers in different doses were applied (Table 15). In considering the different fertilizer doses, F_3 (High NPK) showed the highest N content (0.097%) and the lowest N content (0.061%) was observed in the F_0 treatment where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizers showed significant effect on the N content of soil after harvest (Table16). The highest N content of crop-harvested soil (0.11%) was recorded in the treatment combination of V_1F_3 (Low vermicompost + High NPK). On the other hand, the lowest N content (0.053%) was recorded in V_0F_0 (No vermicompost + No NPK). 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 fertilizer.

Table 16. Combined effect of vermicompost and NPK fertilizers on the OM, total N, available P, exchangeable K and available S contents in the soil after rice harvest

Vermicompost × NPK Fertilizer	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)
V_0F_0	**1.07 i**	**0.053 g**	0.00109h c	**0.00061 i**	**0.0011 h**
V_0F_1	1.20 h	0.060 efg	0.00112h	0.00071 hi	0.0016 efg
V_0F_2	1.33fg	0.077 cdef	0.00181e	0.00120cd	0.0019 c
V_0F_3	1.37efg	0.098 ab	0.00195cd	0.00150 ab	0.0024 b
V_1F_0	1.38efg	0.067 defg	0.00095ij	0.00097 efg	0.0016 fg
V_1F_1	1.29 g	0.078cdef	0.00157 f	0.00110de	0.0018 cde
V_1F_2	1.55bc	0.057g	0.00196 bcd	0.00150 ab	0.0025 b
V_1F_3	1.40def	**0.11a**	0.00205 bc	0.00153 a	0.0019c
V_2F_0	1.47cde	0.059fg	0.00107 hi	0.00080gh	0.0012 h
V_2F_1	1.55bc	0.067 defg	0.00155 f	0.0010 ef	0.0017 def
V_2F_2	1.43 de	0.080cd	0.00190 de	0.0013 bc	0.0019cd
V_2F_3	1.55bc	0.090bc	0.00209 b	**0.00156 a**	0.0024b
V_3F_0	1.48cd	0.066defg	**0.00089 j**	0.00087 fgh	0.0015 g
V_3F_1	**1.77a**	0.065 defg	0.00138 g	0.00093 fg	0.0016 efg
V_3F_2	1.75a	0.079cde	0.00201 bcd	0.00123 cd	0.0019cd
V_3F_3	1.60b	0.090bc	**0.00230 a**	0.00155 a	**0.0028 a**
Level of Significance	0.01	0.01	0.01	0.01	0.01

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

4.5.3 Phosphorous content of soil

A significant variation was observed in the P content of soil in the rice field after harvest where the field was manured with different doses of vermicompost (Table14). Among the different doses of vermicompost, V_0 (No vermicompost) treatment showed the highest P content (0.0031%) after the harvest of crop. On the other hand, the lowest P content (0.0016%) was observed in the V_1 and V_3 treatments.

There was a significant variation in the P content of soil after harvest of the crop when different combinations of fertilizers at different doses were applied (Table 15). Among the different combinations of fertilizer doses, F_0 (No NPK) showed the highest P content (0.027%) and the lowest P content (0.0014%) was observed in the doses of F_1 (Low NPK).

Combined effect of different doses of vermicompost and fertilizer produced significant variarion in respect of P content of soil after the harvest of rice (Table 16). The lowest P content of crop harvested soil (0.00089%) was recorded in the treatment combination of V_3F_0 (High vermicompost + No NPK). On the other hand, the highest P content (0.00230%) was recorded in V_3F_3 (High vermicompost + High NPK) treatments

4.5.4 Potassium content of soil

Significant variation was recorded in the K content of soil in the rice field after harvest of the crop where different doses of vermicompost were applied (Table 14). Application of vermicompost at the rate of 2 t ha^{-1} showed the highest K content (0.0013%) and the lowest K content (0.0010%) was observed in the V_0 treatment where no vermicompost was applied.

There was a significant variation in the K content of soil after harvest when different combinations of fertilizers were applied (Table 16). Fertilizer dose F_3 (High NPK) showed the highest K content (0.0015%) and the lowest K content (0.00081%) was recorded in the F_0 treatment (No NPK).

Combined effect of different doses of vermicompost and fertilizers produced significant variarion in respect of K content of soil after the harvest of rice (Table 16). The lowest K content of crop harvested soil (0.00061%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPK). On the other hand, the highest K content (0.00156%) was recorded in V_2F_3 (Medium vermicompost + High NPK) treatments, which was statistically similar with V_3F_3 and V_1F_3 treatments.

4.5.5 Sulphur content of soil

Significant variation was recorded in the S content of soil after rice harvest where the plots were incorporated with different doses of vermicompost (Table 14). The low dose of vermicompost, V_3 (6 t ha^{-1}) resulted the highest S content (0.0020%) after the harvest of the crop and the lowest S content (0.0017%) was observed in the V_1(2 t ha^{-1}) treatment where low doses of vermicompost was applied.

Significant variation in the S content of soil after harvest was obtained when different combinations of fertilizers at different doses were applied (Table 15). Fertilizer dose, F_3 (High NPK) showed the highest S content (0.0024%) and the lowest S content (0.0014%) was observed in the F_0 treatment where no fertilizer was applied.

The effect of combined application of different doses of vermicompost and fertilizers showed significant differences in respect of S content of soil after rice harvest (Table 16). However, the lowest S content of crop-harvested soil (0.0011%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPK), and the highest S content (0.0028%) was recorded in V_3F_3 (High vermicompost + High NPK) treatment combinations.

Chapter 5

Summary and Conclusion

Chapter 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Sher-e-Bangla Agricultural University Farm (SAU Farm), Dhaka 1207 (Tejgaon series under AEZ No.28) during the *Kharif-1* season of 2005 to study the effect of organic and inorganic fertilizers growth ,yield, and nutrient uptake of rice. The soil was silty loam in texture having pH 5.9, organic matter 1.09%. Randomized complete block design was followed with sixteen treatment combinations having unit plot size of 4m x 2.5m ($10m^2$) and replicated thrice. Four rates of vermicompost 0, 2, 4, and 6 t ha^{-1} (designated as V_0, V_1, V_2 and V_3) and four rates of NPK designated as F_0 (No N, No P_2O_5, No K_2O), F_1 (50, 40, 30kg ha^{-1} N, P_2O_5, K_2O, respectively), F_2 (80, 60, 50kg ha^{-1} N, P_2O_5, K_2O, respectively) and F_3 (110, 80, 70 kg ha^{-1} N, P_2O_5, K_2O, respectively) were used. The treatments were V_0F_0 Control (No vermicompost + No NPK), V_0F_1 (No vermicompost + Low NPK), V_0F_2 (No vermicompost + Medium NPK), V_0F_3 (No vermicompost + High NPK), V_1F_0 (Low vermicompost + No NPK), V_1F_1 (Low vermicompost + Low NPK), V_1F_2 (Low vermicompost + Medium NPK), V_1F_3 (Low vermicompost + High NPK), V_2F_0 (Medium vermicompost + No NPK), V_2F_1 (Medium vermicompost + Low NPK), V_2F_2 (Medium vermicompost + Medium NPK), V_2F_3 (Medium vermicompost + High NPK), V_3F_0 (High vermicompost + No NPK), V_3F_1 (High vermicompost + Low NPK), V_3F_2 (High vermicompost + Medium NPK), V_3F_3 (High vermicompost + High NPK). Nitrogen from urea, P_2O_5 from TSP and K_2O from Muriate of potash (MP) were used. One third of the urea and the whole required amounts of TSP and MP fertilizers and vermicompost were applied in plot as per treatment combination during of the final land preparation (puddling). The rest of the urea was top dressed in two equal splits at 15 and 35 days after transplanting of the seedlings. Rice seedlings cv. Shraboni were transplanted on 26th May, 2005 and the crop was harvested on 18th August, 2005. Intercultural operations were done as and when required. The data were collected plot wise for plant height, panicle height, flag leaf height, number of grains per panicle, % of spikelet sterility , weight of 1000 grains, grain and straw yields. The post harvest soil samples were analyzed for organic matter, N, P, K and S contents. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT at 5% level. The results of the experiment are stated below.

Grain and straw yields of rice responded significantly to the application vermicompost and NPK fertilizers. The highest grain (4.80 t ha^{-1}) and straw yields (7.75 t ha^{-1}) were obtained with V_3F_2 (High vermicompost + Medium NPK) treatment. The lowest grain (3.30 t ha^{-1}) and straw yields (5.25 t ha^{-1}) were recorded with V_0F_0, where no vermicompost nor fertilizers were applied.

The highest (108.3) and lowest (59.33) number of grains /panicle were recorded with V_3F_2 and V_0F_0 treatments, respectively. The highest (34.0) and the lowest (26.0) percentage of spikelet strility were obtained with V_2F_1 and V_0F_0 treatemtns, respectively.

The highest plant height, panicle and flag leaf length of 119 cm, 28.40 cm and 42.0 cm, respectively were recorded with the application of high vermicompost combined with medium doses of NPK fertilizers (V_3F_2). The lowest plant height, panicle and flag leaf length of 96.67 cm, 20.50 cm and 28.0 cm, respectively were obtained inthe treatment which received no vermicompost and fertilizers (V_0F_0).

Both the grain and straw yields and the heights of plant, panicle and flag leaf showed decline when theNPK doses were increased along with the high dose of vermicompost (V_3F_3).

Therefore, the application of vermicompost at the rate of 6 t ha^{-1} along with 80, 60 and 50 kg N, P_2O_5 and K_2O ha^{-1}, respectively is suitable forthe optimum production of rice (cv, BR-26, Shraboni).

The N, P, K and S contents and uptake of these nutrients by rice plant were influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, K and S content in straw (1.54%, 2.23% and 0.28% after harvest, respectively) were recorded in V_3F_3(High Vermicompost + High NPK) treatment except for P which showed highest value (0.87 %) in V_2F_3 (Medium Vermicompost +High NPK). The lowest N, P, K and S content (0.49%, 0.431%, 1.40% and 0.056%, respectively) were obtained with V_0F_0 treatment.

The highest uptakes of 184.8 , 97.07, 234.1 and 33.24 kg ha^{-1} of N, P, K and S respectively were recorded with V_3F_3 treatments and the lowest uptakes of 40.58, 116.0 and 11.64 kg ha^{-1} of N, K and S, respectively by rice plant at harvest stage were found in V_0F_0 (No vermicompost + No NPK). The lowest P uptake (30.74 kg ha^{-1}) by rice straw was obtained with V_3F_0.

The post harvest soil properties such as organic matter, total nitrogen, phosphorus, potassium, and sulphur contents showed increased due to the combined application of vermicompost and fertilizers compared with their status in the soil.

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LIST OF ABBRIVIAT

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
@	At the rate
CEC	Cation Exchange Capacity
cm	Centimeter
$CuSO_4.5H_2O$	Green vitriol
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
DMRT	Duncan's Multiple Range Test
e.g.	example
et al	and others
FYM	Farm Yard Manure
G	Gram
H_3BO_3	Boric acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
i.e	that is
K	Potassium
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2SO_4	Potassium Sulfate
LSD	Least Significant Difference
S	Sulphur
TSP	Triple Super Phosphate
m	Meter
mL	Milliliter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NPK	Nitrogen, Phosphorus and Potassium
NS	Not Significant
OM	Organic matter
pH	Hydrogen ion concentration
^0C	Degree Celsius
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare
GM	Green Manure
PU	Poultry Manure
P	Phosphorus
M F	Manure and fertilizer
PG	Planting Geometry
LER	Land Equivalent Ratio

ABBREVIATION	FULL WORD
RLD	Root Length Density
B	Boron
Zn	Zinc
NO_3-N	Nitrate-Nitrogen
VC	vermicompost
OM	Organic Manure
RDF	Recommended Dose of Fertilizer
C :N	Carbon Nitrogen Ratio
STB	soil test basis
CD	Cowdung
BGA	Blue Green Alge
DTPA	Di -Ethylene Tetra Amine Petra Acetic Acid
RUP	Udaipur Rock Phosphate
SSP	Single Super Phosphate
P.U.	Prilled Urea
HYV	high yielding varieties
RCC	Rlative Crowding Coefficient

Appendices

Appendix 1. Effect of vermicompost on NPKS uptake by rice plant

Treatment	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)	Sulpher (Kg/ha)
V_0	40.58 b	35.46 b	116.00 c	11.64 a
V_1	53.10 a	39.42 a	129.00 b	11.01 a
V_2	56.08 a	36.76 ab	148.20 a	11.46 a
V_3	53.30 a	30.74 c	150.30 a	11.98 a
Level of Significance	0.05	0.05	0.05	0.05

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

Appendix 2. Effect of NPK fertilizers on NPKS uptake by rice plant

Treatment	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)	Sulpher (Kg/ha)
F_0	40.58 d	35.46 d	116.00 c	11.64 c
F_1	53.08 c	51.06 c	166.20 b	18.00 b
F_2	69.12 b	66.92 b	192.70 a	21.12 ab
F_3	77.58 a	73.88 a	191.40 a	23.00 a
Level of Significance	0.05	0.05	0.05	0.05

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

Appendix 3. Combined effect of vermicompost and NPK fertilizers on NPKS uptake by rice plant

Treatment	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)	Sulpher (Kg/ha)
V_0F_0	40.58 i	35.46 h	116.00 f	11.64 g
V_0F_1	53.08 h	51.06 g	166.20 de	18.00 f
V_0F_2	69.12 fg	66.92 e	192.70 bcd	21.12ef
V_0F_3	77.58 e	73.88 d	191.40 bcd	23.00 de
V_1F_0	53.10 h	39.28 h	129.00 f	11.01g
V_1F_1	65.46 g	64.00 ef	170.10 cde	17.46 f
V_1F_2	75.46 e	75.00 d	211.00 ab	23.42 de
V_1F_3	162.30 b	89.00 b	224.60 ab	27.32 bc
V_2F_0	56.08 h	36.51 h	148.60 ef	11.46 g
V_2F_1	50.52 h	60.24 f	173.00 cde	18.88 f
V_2F_2	74.21 ef	82.65 c	207.80 abc	23.64 de
V_2F_3	165.00 b	96.55 a	222.20 ab	30.48 ab
V_3F_0	53.33 h	30.74 i	150.30 ef	11.98 g
V_3F_1	88.54 d	76.30 d	170.00 cde	25.28 cd
V_3F_2	96.64 c	92.29 b	170.50 de	28.48 bc
V_3F_3	184.80 a	97.07 a	234.10 a	33.24 a
Level of Significance	0.05	0.05	0.05	0.05

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