EFFECTS OF VERMICOMPOST ON GROWTH AND YIELDS IN RICE FOR MINIMIZING THE USE OF INORGANIC FERTILIZERS

A THESIS

BY

OMAR MOHAMED RIRASH

STUDENT NO.: 1605577

SESSION: 2016-2017

SEMESTER: JULY – DEEMBER, 2017

MASTER OF SCIENCE (MS)

IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJAPUR

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Submitted to the Department of Soil Science
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December, 2017

DEDICATED

TO MY

BELOVED PARENTS

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ABSTRACT

The field experiment was carried out at research central field, Hajee Mohammad Danesh Science Technology University, Dinajpur. During the period from December, 2016 to April, 2017 to evaluate the effect of vermicompost for the growth and yields of rice (BRRI dhan 29). The main aim of the study was to assist and compare the vermicompost and inorganic fertilizer with recommended doses for growth and yield of rice to minimize the use of synthesis fertilizer. The experiment field was four replication and five treatments laid out in a Randomized Complete Block Design (RCBD). The treatments were T_1 (full doses of N, P, K and S), T_2 (Vermicompost 5 t ha^{-1}), T_3 (Vercompost 2.5 t ha^{-1}), T_4 (vermicompost 2.5 t ha^{-1} +50% N, P, K and S of recommended doses), T_5 (Vermicompost 2.5 ton/ ha^{-1}+33.3% N, P, K and S of recommended doses). Application of vermicompost and inorganic fertilizer significantly increased the yield components grain and straw yield of rice. Application of vermicompost resulted higher yield parameters such as plant height (95 cm), grains $panicle^{-1}$ (175), and spikelet $panicle^{-1}$ (14), grain yield (7.4 t ha^{-1}), biological yield (11.3 t ha^{-1}) these results were recorded in T_2 and $T_{1.}$AvailableN, P, K, and S content in post harvest soil was influenced by application of vermicompost and inorganic fertilizer. From the above discussion the highest yield was in T_2 with the application of vermicompost (5 t ha^{-1}) which was statistically similar to the T_1 with the application of full doses of N, P K and S, so that the application of vermicompost (5 t ha^{-1}) is a similar to the full doses of N, P, K and S and should be recommended to the farmers to use vermicompost which was cheap and available to the rural area and saved the cost.

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SYMBOLS AND ABBREVIATION

°C	= Degree Celsius
AEZ	=Agro Ecological Zone
cm	= Centimeter
DAS	= Days after Sowing
VC	= Vermycompost
DMRT	= Duncan's Multiple Range Test
e. g	= For Example
et al.	=Etalia
G	=Gram
LSD	= Least Significant Difference
RCBD	= Randomized Complete Block Design
DAT	= Days after Transplanting
Ha^{-1}	= Per hectare
Kg	= Kilogram
SRDT	= Soil Resources Development Institute
CEC	= Cation Exchange Capacity
T	= Tones
SOM	= Soil Organic Matter

CHAPTER I

INTRODUCTION

Bangladesh is an agricultural country with a large population, current population of Bangladesh is 160 million and growth rate is 1.37% (BBS, 2014). Most of the people of this country depend on agriculture. Rice (*Oryza sativa* L.) is the staple food of Bangladesh. About 76% of the people live in rural areas, and 47.5% of the total manpower is involved in agriculture. In Bangladesh, agriculture contributes 19.3% of the gross domestic product (GDP) of the country (Bangladesh Finance Bureau, 2014).The agriculture of this country is governed by extensive rice (*Oryza sativa* L.) cultivation, which is the principle carbohydrate supplying food crop for its increasing population. Bangladesh is the world's sixth largest rice-producing country. Rice is the staple food of about 160 million people in Bangladesh. It is deeply in grained in Bangladesh culture and even the word 'food' and 'rice' are synonymous in Bengali. In Bangladesh, rice dominates over all other crops and covers 77% of the total cropped area and 93% farmers grow rice. Unfortunately, the rice in Bangladesh is low considering the other rice growing countries in Asia. Because, the national average rice yield in Bangladesh (4.2 t ha^{-1}) is very low compared to those of other rice growing countries, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}) (BBS, 2012).The total area and production of rice in Bangladesh are about 11.7 million hectares (m ha) and 31.98 (mm ha) tons respectively (BBS, 2012), it provides about 70% of direct human calories intake, making it the most important food crop in Bangladesh. Rice is the most important crop within the sector contributes for about 92% of the total food grains produced in the country. In respect of area and production of rice, Bangladesh ranks fourth following China, India and Indonesia (FAO, 2013).The efficient N management can increase crop yield and reduce production cost. An increase in the yield of rice by 70 to 80% may be obtained from proper application of N-fertilizer, the optimum dose of N fertilizer plays vital role for the growth and development of rice plant and its growth is seriously hampered when lower dose of N is applied, which drastically reduced yield; further, excessive N fertilization encourages excessive vegetative growth which make the plant susceptible to insect pests and diseases which ultimately reduces yield. Depleted soil fertility is a major constrain to higher crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrient in soils. The farmers of this country use on an average 102 kg nutrients ha^{-1}annually (N 70kg + P 24 kg + K 6 kg + 2 kg S and Zn) while the crop removal is about 200 kg ha^{-1} (Islam *et al.*, 1994). In Bangladesh, most of the cultivated soils have less than 1.5% organic matter while a good agricultural soil should contain at least 2% organic matter (Ali, 1994).Moreover, this important component of soil is declining with time due to intensive cropping and use of higher dose of chemical fertilizers with little or no addition of organic manure in the farmer's field. More recently, attention is focused on the global environmental problems; utilization of organic wastes, vermicompost and poultry manures as the most effective measure for the purpose. Organic fertilizer enhances soil porosity by increasing regular and irregular pores and causes a priming effect of native soil organic matter. Application of both chemical and organic fertilizers needs to be applied for the improvement of soil physical properties and supply of essential plant nutrients for the growth of the plant and increase the yield. The aimed of the research was to minimize the use of inorganic fertilizer and to evaluate the effect of vermicomposting on growth and yield of BRRI dhan29 rice, also encourages the applying of organic fertilizer like vermicompost to maintain the physical properties of the soil and remained the soil with health. Vermicompost is the microbial composting of organic wastes through earthworm activity to form organic fertilizers which contain higher level of organic matter, organic carbon, total and available N, P, K and micronutrients, microbial and enzyme activities (Edwards and Bohlen, 1996; Ranganathan, 2006; Parthasarathi *et al.*, 2007).The use of vermicompost increases crop yield and lesses dependence on chemical fertilizer (Adorado *et al.*, 2003). Under the scenario, balanced fertilization and complementary use of inorganic fertilizers with vermicompost and pressmud will go a long way in both improving the yield as well as improving the soil quality. Currently, rice occupies11.42 mh of land and overall production of rice is about 34.23 mt (BBS, 2013) Vermicompost has been considered as a soil additive to reduce the use of mineral fertilizers because it provides required nutrient amounts, incrassation exchange capacity and improves water holding capacity (Tejada and Gonzaler, 2009).Vermicompost not only increases yield of rice but can also substitute chemical fertilizer to some extent(Sharma *et al*, 2008; Guera, 2010).Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity (Satyanarayana *et al.*, 2002). However, the use of organic manures alone might not meet the plant requirement due to presence of relatively low content of nutrients. Application of organic manure with chemical fertilizer accelerates the microbial activity, increases nutrient use efficiency (Narwal and

Chaudhary, 2006) and enhances the availability of the native nutrients to the plants resulting higher nutrient uptake. Therefore, in order to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in combination with inorganic fertilizers to obtain optimum yields (Ramalakshmi *et al.*, 2012).Keeping these facts in mind, research has been launched to study the effect of combined application of vermicompost and chemical fertilizers on yield and yield attributes of boro rice. In my research work was therefore, undertake the following objectives.

1- To minimize the use of inorganic fertilizer with adding for vermicompost.
2- To reduce long and short time impact of chemical fertilizer on soil and environment by using vermicompost.
3- To investigate any promotion of utilizing vermicompost fertilizer.

CHAPTER II

LITERATURE REVIEW

2.1 The effect of chemical fertilizer on growth and yield of rice

N, P, K, S and Zn, of which the three major elements are most important both in the terms of the extent of their deficiencies in the soils, and in terms of their potential for crop yield increases or losses. N is the nutrient element limiting growth in most of the rice soils (Savant and Datta, 1982), and there have been indications that many rice soils of Bangladesh are becoming deficient in P, K,S and Zn (BARC, 2005). The decline in productivity of rice and wheat with continuous cropping was related to deficiency of P, K, S, Zn and imbalanced nutrition (Kumar and Yadav, 2005). Purposefully, a particular nutrient stress created through missing element technique from complete treatment and its reverse management (addition of omitted nutrient in half part of the plot) effect in increasing yield was considered as a measuring stick of nutrient efficacy. The objective of this long-term study was to measure the extent of each major nutrient exclusion effect in soil to decrease yield and simultaneously their application in soil to increase rice yield.

2.1.1 Nitrogen fertilizer

N is the nutrient which limits the most the rice production worldwide. In Asia, more than 90 percent of the world's rice is produced about 60% of the N fertilizer consumed is used on rice (Stangel and De Dutta, 1985). Conjunctive use of organic material along with fertilizer has been proved an efficient source of N. Organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Returning residues like green manure to the soil is necessary for maintaining soil organic matter, which is important for favorable soil structure, soil water retention and soil microbial flora and fauna activities. Use of organic manures in conjunction or as an alternative to chemical fertilizer is receiving attention. Green manure, addition to some extent, helps not only in enhancing the yield but also in improving the physical and chemical nature of soils. The excessive application of chemical fertilizers made it imperative that a part of inorganic fertilizer may be substituted with the recycling of organic wastes. Organic manure has been recorded to enhance the efficiency and reduce the requirement of chemical fertilizers. Partial N substitution through organic manure recorded significant superiority in yield over farmer's practice (Singh and Gangwar, 2000). For sustainability in crop production, it is neither chemical fertilizer nor organic manures alone but their integrated use has been observed to be highly beneficial (Khan *et al.*, 2001). Hence to maintain the sustainable productivity of rice, a set of experiments were carried out to study the effect of organic and inorganic sources on the productivity of rice.

2.1.2 Phosphorus fertilizer

P is the second major plant nutrient. It plays a vital role in several physiological processes viz photosynthesis, respiration, energy storage and cell division enlargement. It is also an important structural component of many biochemical and nucleic acids (DNA, RNA enzymes and co-enzymes) and also stimulates root growth and associated with early maturity of crops (Khan *et al.*, 2007). Application of P fertilizer is one of the most important for higher crop yields; the P accumulation in cultivated soils was a concern for non-point environmental pollution and for efficiency of P resources because of excessive phosphorus in put (Li *et al.*, 2010). P deficit is a most important restrictive factor in plant growth and recognition of mechanisms that increase plant P use efficiency was important (Alinajoati and Mirshekari, 2011). Rice removes about 2 to 3 kg P for 1 mg of grain produced. Although the rice requirement for P is much less than that for N, the continuous removal of P exploits. The soil P reserve if the soil is not replenished through fertilizer or manure application. Chemical P fertilizer was a costly agricultural input for rice framers of the developing world (Saleqe *et al.*, 2004). Management strategies with no P applied to rice were less sustainable in agronomic terms, even though the yield response to in-crop application was inconsistent due to factors other than p deficiency. Raising rice yields beyond the present level of 5/5 t ha^{-1} will require in crop application (singh *et al.*, 2002). Application rates close to or slightly above the amount of P taken up by the crop appears to be sufficient even for high yields and continuous cultivation of rice (Saha *et al*., 2008). According to N and P importance on growth and yield, this study was conducted to determine the effects of N and P fertilizer on growth and yield of rice cultivars Tarom Hashemi.

2.1.3 Potassium fertilizer

Krishnappa *et al.* (2006) reported that increasing K rate increased paddy yields. Potassium applied in split dressings were more effective than applied at transplanting time. Applied K increases soil K availability, K content and the number of grains panicle^{-1}. Dwivedi *et al*. (2006) conducted an experiment to see the effect of K level on growth, yield and quality of hybrid rice. They observed than 80 kg $k_2$0 ha^{-1} better in obtaining higher production. Application of K increased the protein content in rice grains significantly.

Singh *et al.* (2006) conducted an experiment in a silt loam soil to evaluate the effect of K and K levels on growth, yield and seed quality of hybrid rice. They reported that 80kg $k_2$0 ha^{-1} was found better to obtain higher production and good quality of hybrid rice.

2.1.4 S fertilizer

S is an essential macronutrient nutrient for plants ranked four after N, P and K because of its indispensable role in proteins synthesis, vitamins, enzyme and flavoured compounds in plant (Bera and Ghosh, 2015; Islam *et al.,* 2016). About 90% of plant S present in amino acid (methionineand cysteine) and a variety of metabolites(thiamine,thiamine,pyrophosphateglucosinolates,glutathioneand phytochelati ns), which play a pivotal role in building blocks of protein, formation of chlorophyll, acti vation of enzymes etc. (Tewari *et al.*, 2010; Hoefgen and Nikiforova, 2008) Furthermore, deficient supply of S. in soil causing lower uptake of nitrate hence retards the activity of nitrate reeducates as well as N metabolism in plants (Prosser *et al.,* 2001; Abdallah *et al.,* 2010). In Bangladesh, S deficit soils ranked third among problem soils, which is prominent in light-textured soils. About 3.95 m ha of land are S. deficient, which represents approximately 16 % of the total problem soils in Bangladesh (Huq and Shoaib, 2013). This area gradually increasing due to intensive agriculture practices, following multiple cropping systems in association with using of S free fertilizer and no use of organic manures. Unfortunately, most of the farmers of this country often overlook to maintain an optimum S level in their field; even sometimes, they are confused with S deficiency symptoms with P or N deficiencies or Al toxicity. It is worthy to mention that the critical level of S for Bangladesh soil has been determined as 10 µgg^{-1} soil. To obtain higher yield, farmers currently use excess amount of gypsum, ammonium sulphate, zinc sulphate, etc. As S fertilizers to the soils to replenish S deficiency but it is not a good practice for the soils as well as environments in the long run. However, farmers of Bangladesh transplant rice seedlings without maintaining the optimum level of S. Therefore, the present study was undertaken to study the effect of different levels of S on nutrient uptake by BRRI dhan 29 and to find out the optimum level of S for profitable rice production.

2.2 Effect of organic manure on crop growth and yield

The long-term use of inorganic fertilizers without organic supplements damages the soil physical, chemical and biological properties and causes environmental pollution (Albiach *et al.,* 2000). Organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients turnover and many other related physical, chemical and biological parameters of the soil (Albiach *et al.,* 2000). Orozco *et al.* (1996) and Parthasarathi (2004) reported that vermiform post contains nutrients in forms that are readily taken up by the plants, such as nitrates, exchangeable P and soluble K, CA and Mg. Tomati *et al.,* (1990) and Parthasarathi *et al.,* (2006) also reported that vermicompost contains higher amount of humus acid content and biologically active substances such as plant growth regulators. Vasanthi and Kumaraswamy (1999) reported that paddy grain yields were significantly higher in plots treated with vermicompost plus N, P, K than in the treatment that received NPK alone. Effects of application of vermicompost on different types of soil and the nutritional analysis of plants, particularly in crops raised on different soil types have not been studied so far. Hence this paper deals the effect of influence of vermicompost, vermicompost supplemented with chemical fertilizer (NPK) and inorganic chemical fertilizer on various physical, chemical and biological features of two different soils -clay loam and sandy loam and the growth, yield and nutritional quality of beans (*Phaseolus vulgaris*). Vermicompost contains most nutrients in plant-available forms such as nitrates, phosphate sand exchangeable calcium and soluble K (Orozco *et al.,* 1996). There is accumulating scientific evidence that vermicomposts can influence the growth and productivity of plants significantly (Edward, 1998). Various greenhouse and field studies have examined the effects of a variety of vermicomposts on a wide range of crops including cereals and legumes (Kaushik and Garg, 2003), vegetable (Tomati *et al.,* 1990; Wilson and Carlile, 1989; Subler *et al.,* 1998; Atiyeh *et al.,* 2000b), ornamental and flowering plants (Atiyeh *et al.,* 2000b) and field crops (Arancon *et al.,* 2004). Annul application of adequate amounts of some organic residues (vermicompost) led to significant increase in soil enzyme activities such as urease, phosphor monoesterase, phosphodiesterase and anysulphatase (Albiach *et al.,* 2000a). Plant growth-promoting bacteria (PGPB) directly stimulate growth by nitrogen fixation (Han *et al.*, 2005), solubilization of nutrients (Rodriguez and Fraga, 1999), production of growth hormones, 1-amino-cyclopropane-1-carboxylate (ACC) deaminase (Correa *et al.,* 2004) and indirectly by antagonizing pathogenic fungi by production of siderophores, chitinase, β-1, 3-glucanase, antibiotics, fluorescent pigment sand cyanide (Han *et al.,* 2005). Despite of the beneficial effects on growth and yield of plants, higher metal concentration in this material may be a problem and limit its utilization (Jordao *et al.,* 2006). The role of earthworm in the breakdown of organic debris on the soil surface and in the soil turnover process was first highlighted by Darwin (1881). Since then, it has taken almost a century to appreciate its important contribution in curbing organic pollution and providing topsoil in impoverished lands. Since 1978, there has been increasing interest in possible methods of processing organic wastes using earthworm to produce valuable soil additives. Earthworm is specialized to live in decaying organic wastes and can degrade it into fine particulate materials, which are rich in available nutrients with considerable potential as soil additives to revive the productivity status of soil. Earthworm can serve as nature's plowman and they form nature's gift to produce good humus by minimizing the time of humification of organic materials. Vermicomposting is the application of earthworm in producing vermin fertilizer, which helps in the maintenance of better environment and results in sustainable agriculture (Senapati, 1996). Earthworm can consume practically all kinds of organic wastes, consume two to five times its body weight and after using 5-10 per cent of the feed stock for its growth, excrete mucus coated undigested matter as worm casts. It is estimated that 1000 tonnes of moist organic matter can be converted by earthworms into 300 tone of compost (Gunathaliagaraj, 1994). In this review the available literature on the effect of vermicompost application on physical properties of soils, organic matter and nutrient availability, uptake of nutrients and crop growth and yield of rice crop are reviewed.

2.3 Effect of vermicompost on organic matter and nutrient availability

Effect on soil organic carbon content worm casts ingested soil often have much higher content of soil organic carbon and nutrients than the surrounding soil (Lee,1985). Mulongoy and Bedoret (1989) reported that organic carbon and total N contents were significantly higher in drill sphere than those of adjacent soil. Casts deposited by earthworms may participate in the accumulation of organic matter through increased organic matter produced in the ecosystem and the protection of soil organic matter in structures of the drillosphpere (Martin, 1991). The organic carbon content is increased by 4.1-21.0 per cent for burrow wall material and by 21.2-43.0 per cent for worm casts. The carbonate content from casts was reduced by more than 50 per cent (Zhang and Schrader, 1993). Kale, 1994 reported that vermin composting replenished the organic matter content of the soils. The organic matter content in worm casts was about four times more than in surface soil, with mean values of 48.2 and 11.9 g kg respectively (Khang *et al.,* 1994).

2.3.1 Available nitrogen

Available N: The enrichment of earthworm casts with available nutrients compared to the surroundings has been observed by Lee (1985). Earthworm rejects significant amounts of nutrient in this casts. Nitrogen is mainly excreted as ammonium in the urine released by the worm, it is thus mixed with. The soil and found in the casts (Laverack, 1963; Lee, 1985). Bouche and Ferries (1986) reported that 15^{N} labeled N from earthworm was rapidly and almost entirely taken up by plants. The earthworm output comprises almost assumable products of excretion such as ammonia and urea. Which is rapidly mineralized thus it represents a potentially significant source of readily available nutrient for plant growth. Earthworm casts were micro site rich in available C and N (Sensson *et al.,* 1984). Earthworm contribution to, the N turnover in cultivated soils ranged from 3to 60 kg (Crossley, 1988; Bostom, 1988). Increased availability of N in worm casts compared to non ingested soil has been reported by several workers (Tiwari *et al.,* 1989; Hullugalle and Ezumah. 1991). Earthworm excretion of nitrogenous compound in urine and mucus may provident particularly labile N source for soil microbes. Earthworm urine contained primarily of ammonium and urea. Mucus composed of mucoprotein with low CN ratio of 3.8 (Scheu, 1991). Lavelle and Martin (1992) inferred that mineralization rates in the soil were increased by up to 10 per cent and this could lead to the release of significant amount of NH_4^+-N. Blair *et al.,* (1997) suggested possible mechanism whereby earthworm microbial interactions can increase soil N availability by reducing microbial immobilization and enhancing mineralization. Bouche *et al.,* (1997) found that the worm activity can increase potential net N mineralization rates and is to accelerate the transformation of N, after increasing availability. Increased nitrate levels were observed in the soil and dissolved organic nitrogen concentration in earthworm ingested plots (Subler *et al.,* 1997).

2.3.2 Available phosphorus (P)

Available P: Worm casts ingested soils were rich in water soluble P, Sharpley and Syers, 1976) and inorganic N (Watanabe, 1975) in comparison with non-ingested soil material. The availability of P was enhanced in casts compared to non-ingested soil (Sharpley and Syers 1978), Devleeschauwer and Lal, 1981, due to increased solubility of P by high phosphates activity (Syers and Springett, 1984). Mansell *et al.,* (1981) showed that incorporation of casts increased the short term availability of P derived from litter by a factor of approximately three. Mackay *et al.,* (1982) have confirmed the effect of earthworm in increasing the availability of P. Basker *et al.,* (1994) reported that the available P was higher compared to the surrounding soil due to soil ingestion by earthworm. Vasanthi and Kumaraswamy (1996) reported that the organic carbon oontent, available status of N, P, K, Ca, Mg and micro nutrients were higher in treatment that received vermieompost plus N, P and K than in the treatment with N, P and K alone.

2.3.3 Available Potassium (K)

Available K: the casts of earthworms contained two to three times more available K than surrounding soils. (Tiwari *et al.*,1989. Becborodov *el al.,* 1990; Hullegalle and Ezumah, 1991). (Basker *et al.,* 1993) reported that the availability of K was enhanced significantly following soil ingestion by earthworm and this must be due to the changes in the distribution of K between non exchangeable to exchangeable forms. Earthworms cannot increase the total amount of nutrient in the soil but can make them more available and they may increase the rate of nutrient cycling, thereby increasing the quantity of nutrients available (Sharpley and Syers, 1997).

2.4 Effect of vermicompost materials in agriculture

Vermicomposting is a process of bio transforming and stabilizing organic materials (often waste) into humus by the combined activity of earthworms and microorganisms (Aira and Dominguez 2008). Earthworms excrete partially digested materials, known as vermicasts or castings, which are more homogeneous in composition than the source material, have reduced levels of contamination, and contain elevated levels of plant growth regulators or symbiotic microbes and organic acids such as humus and folic acids (Edwards, *el at.,* 1988). Vermicomposting refers to production of compost by growing/ breeding earthworms as these worms in the process of feeding on waste cause bio-oxidation by relentless turning, fragmentation and aeration of waste by devouring resulting in homogeneous and stabilized humus like product which is an ideal nutrient for plants thus used as manure. Vermicomposting of biodegradable Municipal Solid Waste and household waste is in vogue in many places and instances but there is no available literature on use of vermicomposting technique for treatment and disposal of infected biomedical waste. There is an emerging commercial trend of aerobically incubating an extract of compost with a carbohydrate and protein source, producing a microbial enhanced liquid (Pant *et al.,* 2009). Known by the agricultural sector as 'compost teas' in the current study this microbial enhanced product is termed ''Compost Extract'' or ''CE'' in short. Compost extract contains nutrients extracted from compost and thus contributes directly to plant nutrition, and also contains organic matter, Improving soil structure and water holding capacity by building soil aggregates. Composting and vermicomposting are quite distinct processes, particularly concerning the optimum temperatures for each process and the types of microbial communities that predominate during active processing (i.e. thermophiles' bacteria in composting, mesophilic bacteria and fungi in vermicomposting). The wastes processed by the two systems are also quite different. (Edwards *et al.,* 1988) reported that vermicompost have a much finer structure than composts and contain nutrients in forms that are readily available for plant uptake. There have also been reports by (Tomato and Galli 1988) of production of plant growth regulators in the vermicomposts. Therefore, they hypothesized that there should be considerable differences in the performances and effects of composts and vermicomposts on plant growth when used as soil amendments or as components of horticultural plant growth media .Application of vermicomposting in combination with NPK fertilizers resulted in higher content of total nitrogen compared to FYM in combination with NPK fertilizers or control. It also resulted in higher content of phosphorus significantly (Kale *et al.,* 1992). The casting by earthworms was seen to improve, the soil organic matter and nutrient status, by recycling available nutrients especially N, P, K, Ca and Mg. Application of coir dust coir pith into soil contributes 20.7 kg N, 10.5 kg, P_2O_5 and 30.8 kg K_2O ha annually. Coir pith being a rich potash source also helps to retain moisture in the soil for a long time.

2.5 Effect of vermicompost on plant growth

Vermicompost significantly stimulates the growth of a wide range of plant species including several horticultural crops such as tomato (Atiyeh *et al.,* 1999; Atiyeh *et al.,* 2000a, Atiyeh *et al.,* 2000b; Atiyeh *et al.,* 2001; Hashemimajd, *et al.,* 2004; Gutiérrez-Miceli *et al.,* 2007), pepper (Arancon *et al.,* 2004a, Arancon *et al.,* 2005), garlic (Argüello *et al.,* 2006), aubergine (Gajalakshmi and Abbasi, 2004), strawberry (Arancon *et al.,* 2004), sweet corn (Lazcano *et al.,* 2011) and green gram (Karmegam *et al.,* 1999). Vermicompost has also been found to have positive effects on some aromatic and medicinal plants (Anwar *et al.,* 2005; Prabha *et al.,* 2007). Such as sorghum and rice (Bhattacharjee *et al.,* 2001). Reddy and Ohkura, 2004), Sunil *et al.,* 2005). Fruit crops such as banana and papaya (Cabanas-Echevarria, *et al.,* 2005), Acevedo and Pire, 2004), and ornamentals such as geranium (Chand *et al*. 2007), marigolds (Atiyeh *et al.,* 2002), petunia (Arancon *et al.,* 2008), chrysanthemum (Hidalgo and Harkess 2002) and poinsettia (Hidalgoy Harkess, 2002b). Positive effects of vermicompost have also been observed in forestry species such as acacia, eucalyptus and pine tree (Donald and Visser, 1989, Lazcano *et al.,* 2010a, 2010b). Vermicompost has been found to have beneficial effects when used as a total or partial substitute for mineral fertilizer in peat-based artificial greenhouse potting media and as soil amendments in field studies. Likewise, some studies show that vermicomposting leachates or vermicompost water-extracts, used as substrate amendments or foliar sprays, also promote the growth of tomato plants (Tejada *et al.* 2008), sorghum (Gutiérrez Miceli *et al.* 2008), and strawberries (Singh *et al*. 2010). Positive effects of vermicompost include stimulated seed germination in several plant species such as green gram (Karmegam *et al.,* 1999), tomato plants (Atiyeh *et al.,* 2000b, Zaller 2007), petunia (Arancon *et al*. 2008) and pine trees (Lazcano *et al.,* 2010a). Vermicompost also has a positive effect on vegetative growth, stimulating shoot and root development (Edwards *et al.,* 2004). The effects include alterations in seedling morphology such as increased leaf area and root branching (Lazcano *et al.,* 2009). Vermicompost has also been shown to stimulate plant flowering, increasing the number and biomass of the flowers produced (Atiyeh *et al.,* 2002; Arancon *et al.,* 2008), as well as increasing fruit yield (Atiyeh *et al.,* 2000b; Arancon *et al.,* 2004a, 2004b; Singh *et al.,* 2008). In addition to increasing plant growth and productivity, vermicompost may also increase the nutritional quality of some vegetable crops such as tomatoes (Gutiérrez-Miceli *et al.,* 2007), Chinese cabbage (Wang *et al.,* 2010), spinach (Peyvast *et al.,* 2008), strawberries (Singh *et al.,* 2008), lettuce (Coria Cayupán *et al.,* 2009), and sweet corn (Lazcano *et al.,* 2011). Nevertheless, despite the large body of scientific evidence showing the positive effects of vermicompost on plant growth and yield, there is also strong evidence that these effects are not general or constant, and that there is great variability in the magnitude of the effects reported in different studies. In fact, some studies report that vermicompost may decrease growth and even cause plant death (Roberts *et al.,* 2007; Lazcano *et al.,* 2010c). The variability in the effects of vermicompost may depend on the cultivation system into which it is incorporated, as well as on the physical, chemical and biological characteristics of vermicompost, which vary widely depending on the original feedstock, the earthworm species used, the production process, and the age of vermicompost (Rodda *et al.,* 2006, Roberts *et al.,* 2007, Warman and Ang Lopez, 2010). There is also a large variation in the effects of vermicompost depending on the plant species or even the variety considered. This was observed in tomato plants where the replacement of a fertilized commercial potting media with vermicompost had different effects on germination, seedling elongation, biomass allocation, fruit morphology and chemical properties of three tomato varieties (Zaller, 2007). Similar variation was observed in an experiment studying the effects of vermicompost and vermicompost extracts on the germination and early growth of six different progenies of maritime pine Lazcano *et al*. (2010a). In this experiment, the speed of maturation increased, relative to the control without vermicompost, in three out of the six pine progenies, decreased in two of the progenies and was unaffected in the other. It may be expected that different hybrids or plant genotypes will respond differently to vermicompost, considering that plant genotype determines important differences in nutrient uptake capacity, nutrient use efficiency and resource allocation within the plant. Different genotypes may therefore enhance root growth or modify root exudation patterns in order to increase nutrient uptake (Kabir *et al.* 1998; Cavani and Mimmo 2007), and all of these strategies will determine the establishment of different interactions with the microbial communities at the rhizosphere level. In fact, after the application of vermicompost to sweet corn crops, the different genotypes showed important differences in their rhizosphere microbial community (Aira *et al.* 2010). In light of this evidence, it is clear that vermicompost constitutes a promising alternative to inorganic fertilizers in promoting plant growth. However, further research into the exact mechanisms and circumstances that stimulate plant growth by this organic substrate is necessary in order to maintain consumer confidence in this type of fertilizer.

2.6.1 Effect of vermicompost on growth and yield of rice

Effect of vennicompost on crop growth and yield of rice Forgaste and Babb (1972) reported that the cast produced by worm feeding on organic substrate was an extremely homogenous, fertile material suitable for plant growth. A study conducted by Kale and Bano (1986) in summer paddy (IR-20) found that the vegetative growth likes shoot weight, root weight, root and shoot length were influenced by the application of worm cast in better way than chemical fertilizer. Reddy (1988) reported increased growth of rice after addition of cast material from earthworm. (Kale *et al.*,1992) revealed that in lowland rice, applying verrnicompost improved uptake of nutrient, increased level of N, P and microbial load and higher level of symbiotic association resulted in increased effect on growth and yield. Ismail (1993) reporter significantly higher yield of lady finger chillies water melon and paddy by vermicompost application than FYM. Venkataratnam (1994) reported that organic vermicompost could hell to produce additional yield of crops to an ex tent of 30% than normal application o fertilizers. Application of vermicomposttc crops had immediate benefits as the nutrien can be directly absorbed, when applied to dired sown rice, the seedlings turned dark green immediately after emergence (Gunathilagaraj 1994). Angadi and Radder (1996) indicated the use of vermicompost 2.5 t increase grain and straw yield of rice and could save 50 per cent of recommend N P K fertilizers in upland rice. Vasanthi and Kumaraswaml (1996) stated that the grain yield was significantly higher by the treatments that receives vermicompost 5 t ha' + N, P and K at recommended dose compared to the freshmen received N, P and K fertilizer alone.

2.6 Effect of vermicompost on physico-chemical characteristics of soil

The composted organic wastes exert variety of physical, chemical and biochemical influences upon the soil a favorable substrate for plant growth. It maintains the soil in a proper homeostatic state. It also removes excessive amounts of heavy metals such as copper and lead and there by served as a means of detoxification. Kumaresan *et al.,* (1984) reported that there was a slight decrease of pH due to the organic acids released during the decomposition of the various farm wastes. The EC value was also altered by the organic waste application into the soil. There was a significant increase in the available N status due to the application of the various farm waste materials. The available P status was also significantly increased by the application of the various farm waste materials. The application of organic wastes into soil has considerably increased the available K status also. Application of vermicomposting in combination with NPK fertilizers resulted in higher content of total nitrogen compared to FYM in combination with NPK fertilizers or control. It also resulted in higher content of P significantly (Kale *et al.* 1191). The casting by earthworms was seen to improve, the soil organic matter and nutrients status, by recycling vailable nutrients especially N, P, K, Ca and Mg. Application of coir dust coir pith into soil contributes 20.7 kg N, 10.5 kg, P_2O_5 and 30.8 kg K_2O ha annually. Coir pith being a rich potash source also helps to retain moisture in the soil for a long time. Nutrient composition and physico-chemical parameters are subjected to greater changes due to activity of earthworms in food substrates, while mineralization of waste substrates is accelerated by passing of ingested food through gut of earthworms, thus stabilizing N, P, Kcontents in plant available form. The nutrient contents and physico-chemical parameters of vermicompost samples obtained in the present study looked optimum and are considerable tosuch earthworm mediated compost (Kitturmath, *et al.*, 2005) (Karuna Shrestha *et al.* 2011) investigated the physico-chemical and microbiological investigations on rumen content material composted for nine months, fresh vermicasts (obtained after passing the same compost through the guts of a mixture of three species of earthworms: Eiseniafetida Lumbricus. Rubellus and Perionyxexcavates) and microbially enhanced extracts derived from rumen compost, vermicast and vermicast leachate incubated for up to 48 hours. Compared to composted rumen contents, vermicast was only improved interms of microbial biomass C, while vermicast leached extract was significantly higher inNH_4-N; PO_4-P, humic acid, bacterial counts and total microbial activity compared to rumen compost extract. The application of vermicompost increased the growth and yield of paddy besides increasing the levels of total nitrogen, available phosphorous and potassium and micronutrients in the soil. The fertilizing effect of earthworm casts depends on microbial metabolites, mainly growth regulators. Earthworm casts promoted the root initiation and root biomass. The chemical fertilizer application along with vermicompost increased the nutrients uptake and the net production of wheat and sugarcane. Vermicompostis superior to normal compost an increasing the growth of cardamom seedlings. Significant increase in the yield due to sawdust was observed compared to nitrogen's fertilizers application alone. The general vigor of the crop was more with profuse tillering under saw dust compost amendments while with nitrogenous fertilizer alone spans or no tailoring was observed (Anonymous, 1996). Vermicompost contains plant growth regulators and other plant growth influencing materials produced by microorganisms. Vermicompost a by-product of earthworm mediated organic waste recycling is rich in plant nutrients and growth promoting substances. Having shown to promote and sustain crop yields (Reddy *et al.* (2004).

2.7 Importance of vermicompost

2.7.1 Source of plant nutrients

Earthworms consume various organic wastes and reduce the volume by 40–60%. Each earthworm weighs about 0.5 to 0.6 g, eats waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day. These worm castings have been analyzed for chemical and biological properties. The moisture content of castings ranges between 32 and 66% and the pH is around 7.0. The worm castings contain higher percentage (nearly twofold) of both macro and micronutrients than the garden compost. From earlier studies also it is evident that vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. (Sreenivas 1997) studied the integrated effect of application of fertilizer and vermicompost on soil available nitrogen (N) and uptake of ridge gourd (Luffa acutangula) at Andhra Pradesh, India. Soil available Increased significantly with increasing levels of vermicompost and highest N uptake was obtained at 50% of the recommended fertilizer rate plus 10 t ha^{-1} vermicompost. Similarly, the uptake of N, phosphorus (P), Potassium (K) and magnesium (Mg) by rice (Oryza sativa) plant was highest when fertilizer was applied in combination with vermicompost.

CHAPTER III

MATERIALS AND METHODS

The study was carried out the in the central research field of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the Boro season January to May 2017. This chapter contain a brief description of experimental site, soil, climate, crop, treatments, experimental design, land preparation, transplanting of seeding, intercultural operation, harvesting, data recording, preparation of soil samples, plants samples and statistical analysis,

The detail of material methods were prepared below.

3.1 Experimental site

The experiment was conducted in the research field of HSTU, Dinajpur during the Boro season January to May of 2017. The experimental site was at 24.00° N latitude and 90.25° E longitude with an elevation of 34 meter from the sea level which belongs to the AEZ of Old Himalayan Piedmont plain (AEZ 1). The soil is Ranishankail sandy loam, a member of the hypothermic Aeric Haplaquept under the Order inceptisol having only a few horizons, developed under the aquic moisture regime and variable temperature conditions. The morphological, chemical and physical soil characteristics of the soil were presented in the table 3.1.

A. Morphological descriptions of the soil

Morphology	**Characteristics**
Location	Research field, HSTU, Dinajour
AEZ	Old Himalayan Piedmont Plain (AEZ 1)
General soil type	Non-calcareous brown floodplain soil
Parent material	Piedmont alluvium
Soil series	Ranishankail
Drainage	Moderately well drained
Flood level	Above flood level
Topography	High land

B. physical properties of the initial soil sample

Characteristics	Value
Particle size (%)	
Sand (2-0.02mm)	60.0
Silt (0.02-0.002mm)	27.0
Clay (<0.002mm)	13.0
Textural class	Sandy loam

C. Chemical characteristics of the initial soil sample

Characteristics	Content
pH	5.87
Organic matter (%)	1.72
Total N (%)	0.09
Available P (ppm)	14.60
Exchangeable K (me/100g soil)	0.20
Available S (ppm)	1.36

3.2 Crop

The crop of the experiment was BRRI dhan 29, the variety of BRRI dhan 29 was developed by BRRI (Bangladesh Rice Research Institute), Gazipur, Bangladesh in 1994. The characteristics of BRRI dhan 29 are Plant high 95 cm, medium slender and white. Planting time is Rabi, Boro, late October to Mid-November and harvesting time mid-April to early may. The yield of BRRI dhan 29 varieties is 7.5 t ha^{-1}.

3.3 Climate

The experimental site is situated in the subtropical climatic zone, characteristics by the heavy rainfall May to September and scanty rainfall during the rest time. At the growing period of the crop total rainfall was 83mm, relative humidity on January was 84%.

3.4 Land preparation

The land was prepared thoroughly by ploughing and cross ploughing with a power tiller. Every ploughing was followed by laddering to have a good tilth. Weeds and stubbles of the previous crop were collected and removed from the experimental plot before final ploughing, pudling and leveling.

3.5 Experiment design and treatment

The experiment was laid out in Randomized Complete Block Design (RCBD). The experiment field was four replication and six treatments. The total numbers of experimental plots were 20. The size of the unit plot was 2.5m × 2m (5m^2) the spacing between blocks was 20 cm and plot to plot was 20cm.

Treatment code treatment description

T_1: Recommended doses of N, P, K and S

T_2: Vermicompost 5 t ha^{-1}

T_3: Vercompost 2.5 t ha^{-1}

T_4: Vermicompost 2.5 t ha^{-1} +50% N, P, K and S of recommended doses

T_5: Vermicompost 2.5 t ha^{-1}+33.3% N, P, K and S of recommended doses

3.6 Fertilizer does of (kg ha^{-1}) at different treatment

Nitrogen (N)	250	Urea
Phosphorus (P)	100	TSP
Potassium (K)	200	MP
S (S)	50	Gypsum

3.7 Fertilizer and vermicompost application

The full doses of TSP, MOP, Gypsum and Vermicomost manure were applied during the final land preparation. Urea was applied in three equal splits; The first split after 7 days transplanting , the second split as top dressing after 30 days of transplanting while the third one after 60 days of transplanting (panicle initiation stage).

3.8Transplanting Time

Forty days old seedling were uprooted carefully from the seedbed in the morning and transplanted on 10th January 2017 in the main plot. The distance from plant to plant and row to row was 25 cm having 80 hills. Seedling was transplanted in the field at a rate of three seedling hill^{-1}.

3.9 Intercultural operation

Intercultural operation was done for ensuring and maintaining the normal growth of crop.

3.9.1 Weeding

The experimental plots were infested with some weeds, which were controlled by uprooting and removed them from the field at 9 times.

3.9.2 Irrigation

After transplanting the rice, 4 to 5 cm water level was maintained in each plot throughout of period until harvesting time.

3.9.3 Insect and pest control

The panicles were attacked by the pest before 25 days of harvesting like rice bug (*Leptocorisaacuta*), Stink bug (*Oebaluspugnax*) that are sucking the cell sap from the grain making empty and I applied some pesticides like Ashathion also applied some fungicide to prevent from rice blast disease naming Blastin with Dithane M-45.

3.9.4 Harvesting and threshing

The crop was at full maturity on 23 May 2017 and harvested the field on 26th may. The yield of the grain and straw per plot were recorded after threshing, winnowing and drying. The harvested crop in each plot was bundled separately and brought to the threshing floor at the farm section of (HSTU) and have threshed them carefully and measured grain plot and straw plot.

3.9.5 Collection of plant sample

Ten hills were randomly selected from each plot at maturity to record the yield contributing characters. Grain and straw samples were kept for chemical analysis.

3.9.6 Data collection of crop parameters

i. Plant height
ii. Number of tillers
iii. Panicle length
iv. Grains panicle^{-1}
v. Number of filled grains panicle^{-1}
vi. Number of unfilled grains panicle^{-1}
vii. Weight of 1000 grains
viii. Grain yield
ix. Straw yield
x. Biological Yield

3.9.7 Procedures of data collection

The data were recorded on yield and yield components of rice. The yield and yield components were; plant height, no. of tillershill^{-1}, no. of effective tillershill^{-1}, no. of non-effective tillers, panicle length, grains panicle^{-1}, filled grains panicle,$^{-1}$ unfilled grains panicle,$^{-1}$ 1000 grain weight , grain yield, straw yield, biological yield and harvest index.

i. Plant height (cm)

Plant height was measured from the ground level of a plant to the top of a panicle. Plants of ten hills measured and averaged from each plot.

ii. Number of tillers hill^{-1}

Number of tillers per hill^{-1} were counted from selected ten hills of each plot and recorded after calculated them.

iii. Panicle length (cm)

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

iv. Number of grains panicle^{-1}

The grains obtained from each unit of the field have displayed to the sun to dry them and weighed properly. The dried weights of ten plants were added to the other grain yield obtained from the similar plot each of them.

v. Number of filled grains panicle^{-1}

Ten panicles were taken at random from each plot and filled grains panicles^{-1} were counted and made averaged.

vi. Number of unfilled grain panicle^{-1}

Ten panicles were taken at random from each plot and unfilled grainspanicles^{-1} were counted and averaged similar to the filled grains panicle^{-1}.

vii. Grain yield

The grainpanicles^{-1} were obtained from any panicle's spikelet and the total grains were separated in to filled grains and unfilled grain.

viii. Straw yield

Straw yield was gained from each plot of the research field include the straw of ten sample plants were dried in the sun and weighed to record the final straw yield per plot.

ix. Biological yield

Biological yield was calculated by using the formula below.

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

IV. 1000-Seed weight (gm)

1000-seed weight was recorded from each plot after harvest.

3.10 Analysis of soil sample

Soil sample for chemical properties were analyzed in the laboratory of the Department on Soil Science, HSTU, Dinajpur and Soil Research Development Institute (SRDI), Nashipur, Dinajpur. The soil chemical properties under the study were texture, pH, organic matter, total N available P, exchangeable K contents and available S.

3.11 Collection and preparation of soil sample

3.11.1 Initial soil sample

The initial soil sample was collected before land preparation from the plough depth layer (0-15cm).10 sample were taken by means of an auger from 10 location covering the whole experimental plot and mixed thoroughly to make a composite sample. The composite sample was air dried, ground and sieved thorough a 20-mesh and sieve and stored in a plastic bag for physical and chemical analysis. The results were in table No. 3.1.

3.11.2 Post-harvest soil samples

After harvesting the crop, 10 soil samples were collected from each plot at 0-15 cm depth. The soil were air dried, grounded sieved thorough a 20-mesh sieve. Prepared soil sample were stored in plastic bags for chemical analysis only.

3.11.3 Particle size analysis

It was done by the hydrometer method (Bouyoucos,1926) and textural class was determined by plotting the result for % sand, % silt and % clay in the Marshall's triangular coordinating following USDA system.

3.11.4 Soil pH

The soil pH was measured with a glass electrode pH meter using soil water suspension of 1:2.5 as described by Jackson (1962).

3.11.5 Organic matter content

This was estimated following the method developed by Walkley and black (1934).The principle under laying the method was to oxidize the organic matter with the excess of 1N $K_2Cr_2O_7$ solution in presence of concentrated H_2SO_4 and to titrate the remaining un-reacted Cr_2O_7 solution with N $FeSO_4$. Finally, the organic carbon contents were then calculated by multiplying the % organic carbon.

3.11.6 Digestion and determination of total N from soil samples

One g of oven dry ground soil sample was taken in a micro-kjeldahl flask .1.1 g catalyst mixture (K_2SO_4:$CuSO_4.5H_2O$:Se=100:10:1), 3 ml 30% H_2O_2 and 5 ml conc. H_2SO_4 were added into the flasks .The flasks were swirled and allowed to stand for about 10 minutes. Then heating at 380^0 C was continued until the digest was clear and colorless. After cooling the contents were taken into volumetric flasks and volumes were made up to the mark with distilled water. A reagent blank was prepared in the similar manner. These digests were used for N determination. After completion of digestion, 40% NaOH was added with the digests for the distillation. The evolved was trapped in 4% H_3BO_3 solution and 5 drops of the mixed indicator of bromocressol green ($C_{12}H1_4OBr_4S$) and methyl red ($C_{10}H_{10}N_3O_3$) solution. Finally the distillates were titrated with the standard 0.01 N H_2SO_4 until the color changed from green to pink (Bremner and Mulvancy,1982).

3.11.7 Available phosphorus

This was extracted from the soil by shaking with 0.5M $NaHCO_3$ at the pH 8.5 following Olsen *et al.,* (1954). The phosphorus in the extract was determined by developing blue color using $SnCL_2$ reduction of phosphomolybdate complex. The absorbance of phosphomolybdate blue color was measured at 600nm wave length in a spectrophotometer and available P was calculated with the help of standard curve.

3.11.8 Available (S)

Available S was determined by extracting the soil sample with $CaCl_2$ solution (0.15%).The S content in the extract was estimated turbid metrically with K spectrophotometer at 420 nm wave length (Hunter,1974).

3.11.9 Exchangeable potassium (K)

Exchangeable potassium (k) of soil was determined with 1.0 N NH_4OAc (pH 7) extractive reagent. Then K was determined directly with a flame emission spectrometer as described by Black (1965).

3.12 Chemical analysis of plant samples

3.12.1 Preparation of plant samples

Both the grain and straw samples were dried in an oven at 60^0C for 24 hours and then ground by a grinding mill. The prepared sample were then put in paper bags and kept in desiccators until analysis.

3.12.2 Digestion and determination of total N from plant samples

For the determination of N 0.1 g oven dry ground plant samples (both grain and straw) as taken in amicro-kjeldahl flask. 1.1 g ($K_2SO_4:CuSO_4.5H_2O:Se=100:10:1$), 3 ml 30 ml 30% H_2O_2 and 5 ml conc. H_2SO_4 were added into the flasks. The flasks were swirled and allowed to stand for 10 minutes. Then heating was continued until the digest was clear and colorless. After cooling, the content was taken until 100 ml volumetric flasks and the volumes were made up to the mark with distilled water. A reagent blank was prepared in the same way. These digests were used for N determination.

3.13 Statistical analyses

The data collected from the different parameters was statistical analyzed for variance of every crop parameters and also so for the nutrient content and nutrient uptake by the grain and straw and the differences among the treatment means were evaluated by the Duncan’s New Multiple Range Test (DMRT). Data analysis was done by computer using MSTAT software.

CHAPTER 1V

RESULTS AND DISCUSSIONS

This Chapter presents the effects of vermicompost and chemical fertilizer on the growth, yield, grain nutrient concentrations of BRRI dhan29 and post-harvest soil chemical properties. The results have been presented in various tables, figures and discussed under the following subsections.

4.1 Yield components of rice

4.1.1 Plant height

Plant height of rice was responded significantly due of application of vermicompost and inorganic fertilizer (Table 4.1). All treatments influenced to the plant height ranging from 74.1 to 95 cm. The highest plant was found in treatment T_2 (95 cm) which was statistical similar to the treatment T_1 (93.8 cm). The lowest plant height was observed in treatment T_5 (74.1 cm). The treatment may be ranged in order of $T_2>T_1>T_3>T_4>T_5$. Vermicompost is performed better in promoting plant height compared to the inorganic fertilizer treatments.

4.1.2 Panicle length

Panicle length was significantly influenced by the application of vermicompost and inorganic fertilizer (Table 4.1). The highest panicle length of 24.7 cm was found in T_3 which were statistically identical with the treatments of T_2 and $T_{1.}$ The lowest panicle length of 20.9 cm was observed in T_5treatment.The treatment may be ranged in order of $T_3>T_2>T_1>T_4>T_5$. From the above Table 4.1 it may be over concluded with increasing the vermicompost and inorganic fertilizer increased the panicle length of rice also in found same as result was reported by Haque (1999). Babu *et al*. (2001), Ahmed and Rahman (1991) and Apostol (1989) also reported similar results.

4.1.3 Number of tillers hill^{-1}

The different treatments of vermicopst and inorganic fertilizer showed significant variations in respect of number of effective tillers per hill (Table 4.1). Tillers hill^{-1} was ranged from 20 to 26. The highest numbers of tillers (26) was found in T_1 (full does of N, P, K, S) that was statistically similar to the T_2 (25), while the lowest tillers hill^{-1} (18) was observed in T_5that was identically similar to the T_3 and T_4.

4.1.4 Number of spikelet hill^{-1}

The number of spikelet hill^{-1} was significantly affected by the use of vermicompost and inorganic fertilizer. The highest number of spikelet hill^{-1}(14) that was found in T_2 which was statistical identical with T_1 (12) and the lowest number of spikelet (9) was found in T_5 which was also similar by T_4 with the value of 11. The difference between the numbers of spikelet was an affect by utilization of different recommended dose of fertilizers such as vermicompost and inorganic fertilizer.

4.1.5 Grains panicle^{-1}

The grain panicle^{-1} was significantly influenced by the application of vermicompost and inorganic fertilizer. The maximum result of grain panicle^{-1} was obtained (175) in $T_{2.}$ The effect of vermicompost on increasing the number of grains panicle^{-1} was more pronounced as compared to fertilizers. On the other hand, the minimum grain per panicle was observed (115) in T_4. The T_2 was identical with T_1 of the value of (172.5) and T_3 (154.1) which were statistically similar to T_5 with the value of 135, respectively.

4.1.6 Number of filled grain panicle^{-1}

A significant variation in number of filled grains panicle^{-1} was influenced by application of vermicompost and inorganic fertilizer (Table 4.1). The maximum number of filled grain panicle^{-1} (175) was obtained in T_2 which was statistically similar to the treatment T_1 (173). Also the minimum number of filled grain panicle-1 was observed in treatment T_4 (135) which were comparable to the treatment T_5 with the values 135, respectively.

4.1.7 Number of unfilled grain panicle^{-1}

The number of unfilled grain panicle^{-1} was significant variation was measured due to the application of vermicompost and inorganic fertilizer (Table 4.1). The highest Number of unfilled grain panicle^{-1} (33) was found in T_1. On the other hand, the lowest number of unfilled grain panicle^{-1} was observed in T_3 (20). As well as the T_1 was comparable to the others treatment T_2, T_4, T_5 with the values 30, 31, 30, respectively.

4.1.8 Weight of 1000 seeds grain

Weight of 1000 seeds showed statistically significant variation due to the application of vermicompost and inorganic fertilizer (Table 4.1). The highest weight of 1000 seeds (24.99 g) was found from T_4. Abedin *et al.* (1999) reported that the combined application of organic manure and chemical fertilizers increased the 1000-grain weight of rice. Whereas, the minimum weight of 1000 seeds (19.40 g) was observed fromT_5 which was statistically similar to the T_3 with the value (20.40 g). The T_4 was statistically identical with thousand-grain weight of T_2, T_1 values 23.20 g and 21.9 g, respectively.

Table 4.1 Effects of different doses of vermicompost and fertilizer on the yield and yield parameters of rice (BRRI dhan 29)

Treatment	Plant height (cm)	Panicle length (cm)	Number of tillers	Number of spikelets panicle^{-1}	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}	1000 seed weight (g)
T_1	93.8 a	23 ab	26 a	12 a	173 a	33a	21.920 a
T_2	95 a	24.7 ab	25 a	14 a	175 a	30 a	23.203 a
T_3	87.5 b	24.2 a	21 b	11 ab	154 ab	20 b	20.397 b
T_4	81.2 c	21.8 cd	21 b	11bc	135 b	32 a	24.990 a
T_5	74.1 d	20.9 d	18b	9 c	135 b	30a	19.247 C
LSD at 5%	**3.323**	**1.556**	**0.9719**	**0.8101**	**26.56**	**8.509**	**1.775**
CV %	**2.20%**	**3.84%**	**2.51%**	**4.08%**	**9.82%**	**16.78%**	**4.53%**

Treatment code treatment description

T_1: Recommended doses of N, P, K and S

T_2: Vermicompost 5 t ha^{-1}

T_3: Vercompost 2.5 t ha^{-1}

T_4: Vermicompost 2.5 t ha^{-1} +50% N, P, K and S of recommended doses

T_5: Vermicompost 2.5 t ha^{-1}+33.3% N, P, K and S of recommended doses

4.2 Grain and straw yield of BRRI dhan 29

4.2.1 Grain yield

The grain yield of rice varied significantly due to application of vermicompost and inorganic fertilizer (Table 4.2). The grain yield ranged from 5.2 to 7.4 t ha^{-1}. The highest grain yield was recorded in the treatment T_2 (7.4 t ha^{-1}) which was statistically identical with T_1 (7.3 t ha^{-1}). Due to the higher available nutrient and optimum soil properties in the research filed receiving higher doses of inorganic fertilizer. Similar results were also reported by Pandey *et al.* (2009), whereas, the lowest grain yield was observed in T_5 (5.2 t ha^{-1}). The other two of T_3 and T_4 were statistical similar with values of 6.5 t ha-^{1} and 6.1 t ha-1, respectively. The treatment may be ranged in order of T_2>T_1>T_3>T_4>$T_{5.}$

4.2.2 Straw yield

Straw yields also varied significantly by different treatments under study (Table 4.2). The yields of straw varied from 11 to 8.9 t ha^{-1}. The highest straw yield of 11.3 t ha^{-1} was obtained in T_1 and the lowest value of 8.9 t ha^{-1} was recorded in T_5 which was statistical comparable to the other treatments of T_4 and T_3 with the values of 9.3 and 10.2 t ha^{-1}. The treatments may be ranked in the order of T_1>T_2>T_4>T_3>T_5, respectively in terms of straw yield.

4.2.3 Biological yield

The significant variation in biological yield was effected by the utilization of vermicompost and inorganic fertilizer with recommended dose (Table 4.2). The maximum biological yield (18.7 tha^{-1}) was recorded from T_2 which was statistically identical (18.4 t ha^{-1}) with T_1 whereas, the lowest biological yield (14 t ha^{-1}) was obtained from T_5 which was statistical similarly with T_4 (15.3 t ha^{-1}). On the other hand, the treatments may be ranged as the following terms T_2>T_1>T_3>T_4>T_5.

Table 4.2 Effect of vermicompost and fertilizer on the yield (t ha^{-1}) components of rice (BRRI dhan 29)

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
T_1	7.3 a	11.3 a	18.4 a
T_2	7.4 a	11a	18.7 a
T_3	6.5 b	10.2 b	16.6 b
T_4	6.1 b	9.3 c	15.3 c
T_5	5.2 c	8.9 d	14. c
LSD at 5%	**0.12**	**0.44**	**0.66**
CV %	**3.42%**	**2.51%**	**2.27%**

Treatment code treatment description

T_1: Recommended doses of N, P, K and S

T_2: Vermicompost 5 t ha^{-1}

T_3: Vermicompost 2.5 t ha^{-1}

T_4: Vermicompost 2.5 t ha^{-1} +50% N, P, K and S of recommended doses

T_5: Vermicompost 2.5 t ha^{-1}+33.3% N, P, K and S of recommended doses

4.3.1 Nitrogen (%) content in grain

The N content in grain varied significantly in different treatment (Table 4.3). The highest N content of 1.45% was observed in T_2 which was statically identical with T_1 of 1.40%, while the lowest N content in grain of 0.96 % was recorded in T_5. The application of vermicompost and chemical fertilizer increased the N content in grain. The other treatments of T_3, T_4 of the have got the similar values of 1.32% and 1.33%, respectively.

4.3.2 Nitrogen (%) content in straw

The N content in straw was influenced by the application of vermicompost and chemical fertilizer (Table 4.3) ranging from 0.8 to 0.55 %. The highest N content in straw 0.55 % was recorded in $T_{2,}$ which was statistically nearly to the other treatments of T_5, T_3 and T_4 with the values of 0.41%, 0.35% and 0.30%, respectively; on the other hand the lowest nitrogen content in straw 0.8% was obtained in T_1.

Table 4.3 Effect of vermicompost and inorganic fertilizer on N content in rice grain and straw

Treatments	Nitrogen content (%)	
	Grain	Straw
T_1	1.40 a	0.8 d
T_2	1.45 a	0.55 a
T_3	1.33 b	0.35 c
T_4	1.32 b	0.30 c
T_5	0.96c	0.41 b
LSD at % level	**0.014**	**0.017**
CV%	**1.07**	**4.00**

Treatment code treatment description

T_1: Recommended doses of N, P, K and S

T_2: Vermicompost 5 t ha^{-1}

T_3: Vermicompost 2.5 t ha^{-1}

T_4: Vermicompost 2.5 t ha^{-1} +50% N, P, K and S of recommended doses

T_5: Vermicompost 2.5 t ha^{-1}+33.3% N, P, K and S of recommended doses

4.4.1 Chemical properties of post-harvest soil

4.4.1 Available P (ppm)

The content of available P in post-harvest soil was significantly influenced by various treatments of vermicompost and chemical fertilizers (Table 4.4). The initial soil observed on the experimental field was (14.60 ppm). Available P content varied from 34.49 to 22.26 due to application of vermicompost and inorganic fertilizer gave higher value of available P in postharvest soil compared to the control. Highest available P (34.49 ppm) was found in $T_{3,}$ while the lowest available P 22.26 ppm was obtain in T_4 which was statistically similar to the T_5 and T_2 with the values of 26.58 and 28.12 ppm, respectively.

4.4.2 Available S (ppm)

The available S content in soil was influenced by the application of vermicompost and chemical fertilizer (Table 4.4). The initial S available in the soil was 1.36 ppm that was lower than the postharvest ranged from 14.73 to 4.54 ppm. the maximum available S content in postharvest soil (14.73 pmm) was obtained in T_1 and the minimum available S concentration in the postharvest soil (4.54 ppm) was observed in T_3 that was statistically similar to the T_2, T_4 and T_5 with the values of 6.26, 9.27, 9.67 ppm, respectively. The application of organic manure and chemical fertilizer increased the S content in soil of post harvesting when compare the initial soils.

4.4.3 Exchangeable K

Exchangeable K of the postharvest soil was significantly influenced by difference treatments of vermicompost and inorganic fertilizer had significant effected on the exchangeable potassium in the research field (Table 4.4). The initial exchangeable K was 0.20 me100-1g. The highest available potassium in the postharvest soil (0.30 $me100^{-1}g$) was recorded from T_3 which was statistically similar to the T_1, T_4 and T_5 with the values of 0.26, 0.25 and 0.23 $me100^{-1}g$ while the lowest K exchange (0.15 $me100^{-1}g$) was found in T_2. Potassium exchangeable increased due to application of vermicompost and inorganic fertilizer in the research field. These results are similar with the finding of some earlier workers (Saleque *et al.,* 1991) and also (Bharadwaj and Omanwar, 1994).

4.4.4 Total N

The total N content in post-harvest soil varied considerably by different treatment. The total N slightly increased due to application of vermicompost and inorganic fertilizer compared to the initial soil. The total N content in post-harvest soils was ranged from 0.11 to 0.10% as compared to the 0.085% in initial soil. The highest value number of N content in post-harvest soil (0.11%) was recorded T_2 which was statistically similar to the other treatments. This was due to the fact that vermicompost added N in soil and reduced the loss of N in soil. (Bangar *et al.* 1990) found that compost enriched the N content of soil. (Tolanur and Badanur 2003) reported that soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with chemical fertilizer.

4.4.5 Organic matter (%)

Significant variation was found for organic matter content in postharvest soil field due to application of different doses of vermcompost and inorganic fertilizer (Table 4.4). The average soil organic matter content in initial soil was 1.719% (Table 4.3) that was slightly lower than the average organic matter in post-harvest soils ranged from 1.90 to 2.26. The highest average of organic matter (2.26%) was found in T_2 that was statistically identical with T_4 and T_3 due to application of Vermicompost added organic matter in the soil as consequence the amount of organic matter in postharvest soil showed higher values compared to control plot. (Xu *et al.,* 2008) reported that application of chemical fertilizer with organic manure increase soil organic matter; on the other hand the lowest organic matter (1.19 %.) was recorded in T_1.

Table 4.4 Effect of vermicompost and fertilizer on soil properties of post-harvesting of rice (BRRI dhan29)

Treatments	Available P (ppm)	Available S (PPM)	Exchangeable K (meq.100^{-1}g soil)	Total N (%)	Organic matter (%)
Initial soil	14.60	1.36	0.20	0.085	1.02
T_1	28.12	14.73	0.26	0.10	1.19
T_2	34.49	6.26	0.15	0.11	1.90
T_3	22.26	4.54	0.30	0.10	1.01
T_4	26.58	9.27	0.25	0.10	1.06
T_5	30.02	9.67	0.23	0.10	1.04

Treatment code treatment description

T_1: Recommended doses of N, P, K and S

T_2: Vermicompost 5 t ha^{-1}

T_3: Vermicompost 2.5 t ha^{-1}

T_4: Vermicompost 2.5 t ha^{-1} +50% N, P, K and S of recommended doses

T_5: Vermicompost 2.5 t ha^{-1}+33.3% N, P, K and S of recommended doses

4.5 Correlation and regression of research

4.5.1 Grain and plant height

The plant height and grain yield relationship between these two parameters showed positive and significant correlation (Figure 4.5) the correlation co-efficient value of (r = 0.9866). The line of regression X (Plant height) on Y (Grain yield) having Y= 0.1032x-2.4244 revealing that the grain yield dependent on the character of plant height, because the positive slope indicates that the grain yield and plant height was directly correlated as well as increasing the plant height increased the grain yield of rice.

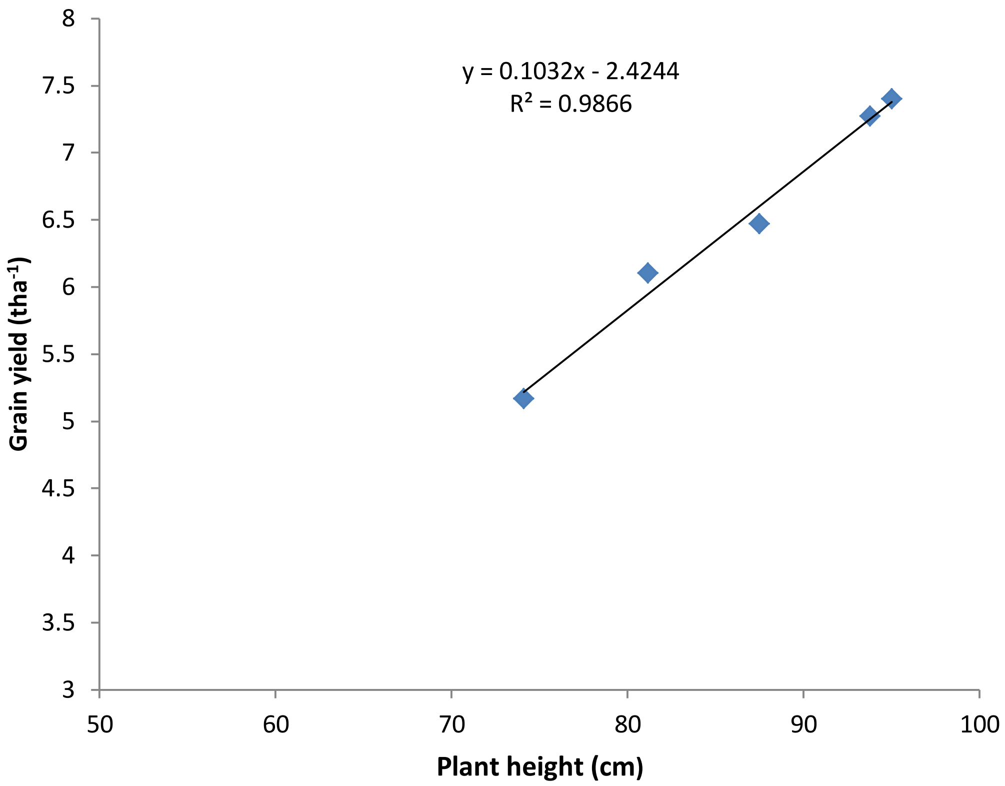

Figure 4.1: Correlation between plant height and grain yield of rice (BRRI dhan 29)

4.5.2 Grain yield and panicle length

The relationship between the grain yield and panicle length (cm) were shown in the figure 4.6. The correlation co-efficient value of (r = 0.6804). The line of regression X (Panicle length) on Y (Grain yield) having equation of Y= 0.4779x-4.4816 was shown in figure 4.5 statistical level had high significant correlation with grain yield and A strong correlation of grain yield with this traits indicated that the grain yield dependent on the panicle length, hence the higher panicle length economically increase the grain yield Previous studies have mentioned similar findings (Lanceras *et al.,* 2004; Muhammed *et al.,* 2007; Yadav *et al.,* 2010; Kiani, 2012).

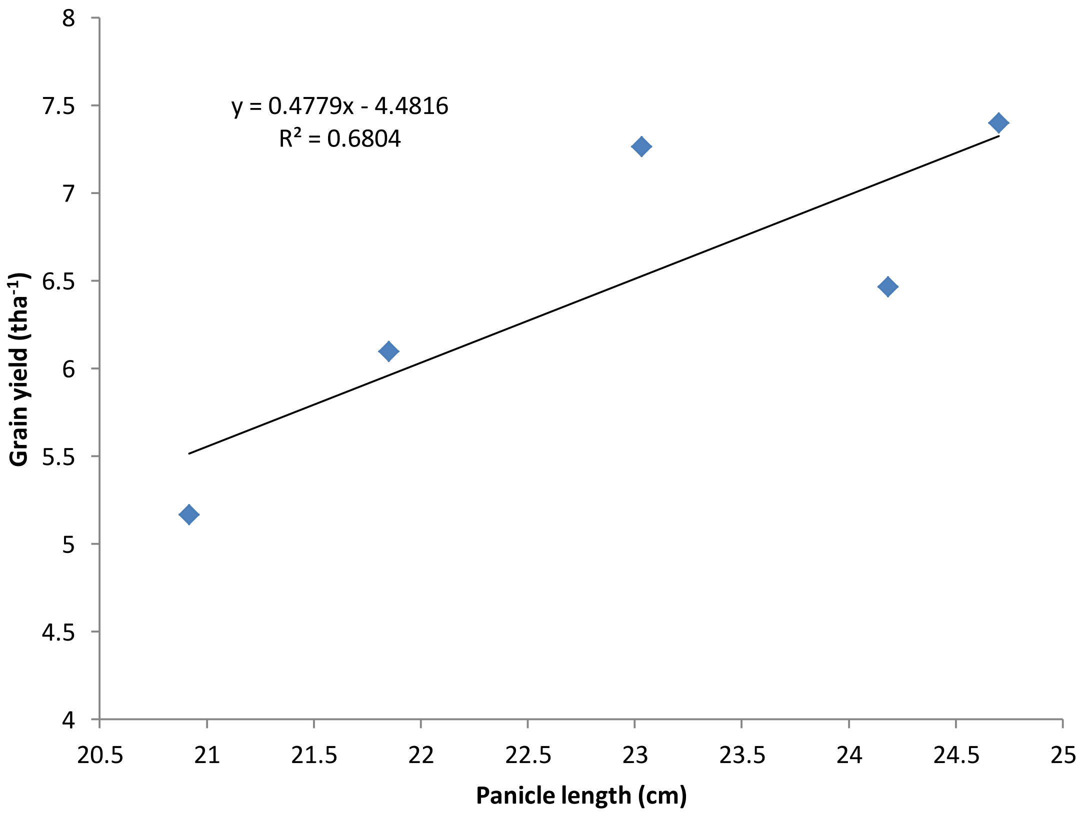

Figure 4.2 Relationship between panicle length and grain yield of rice (BRRI dhan 29)

4.5.3 Grain yield and number of tillers $hill^{-1}$

The relationship between the grain yield and number of tillers hill shown positive and significant correlation those were presented in the figure 4.7. The correlation co-efficient value of grain yield and tillers $hill^{-1}$ were (r = 0.792). The line of regression X (tillers $hill^{-1}$) on Y (Grain yield) having Y=0.3579x -1.5133 was shown in the figure 4.5. The positive slope indicates that the grain yield and tillers $hill^{-1}$ is directly correlated each other thus, due to the increasing of number of tillers $hill^{-1}$ also increased the grain yield.

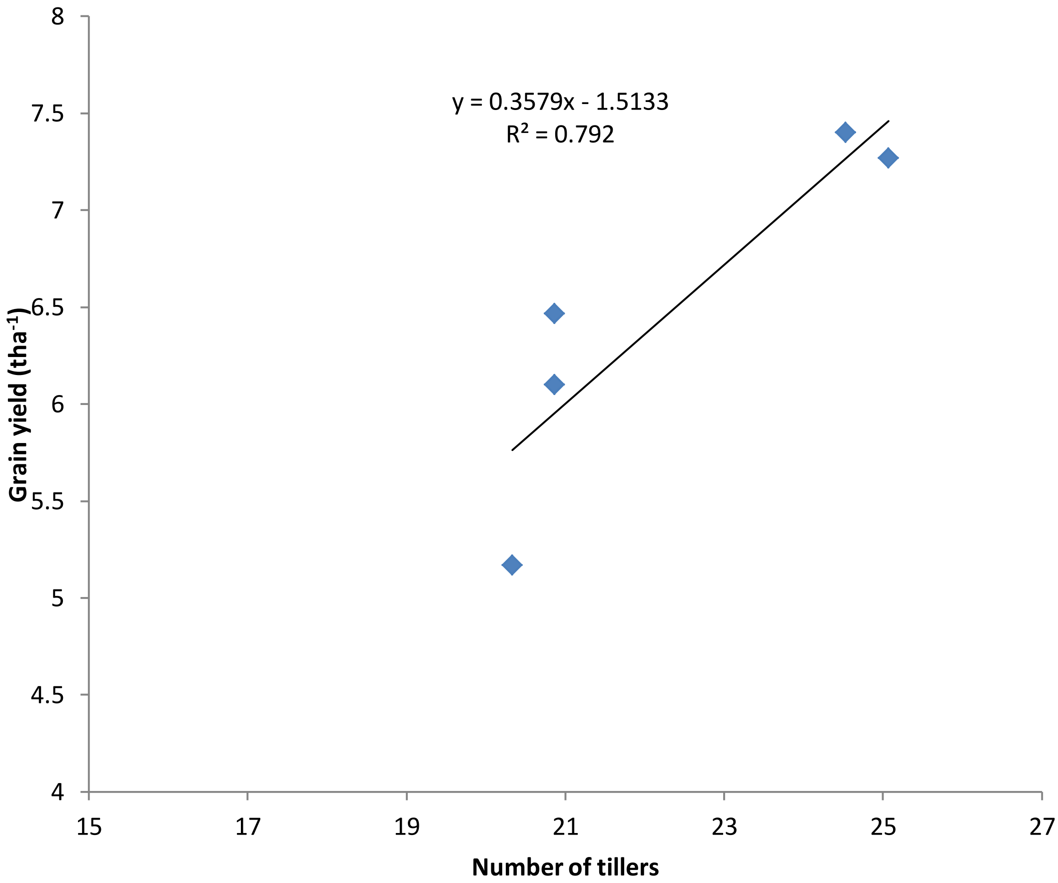

Figure 4.3 Relationship number of tillers $hill^{-1}$ and grain yield of rice (BRRI dhan 29)

4.5.4 Grain yield and spikelet panicle^{-1}

The relationship between the grain yield and spikelet panicle-1shown positive and significant correlation those were presented in the figure 4.6. The correlation co-efficient value of grain yield and spikelet panicle^{-1} were (r = 0.8738). The line of regression X (spikelet panicle^{-1}) on Y (Grain yield) having Y=0.4952x -0.775 was shown in the figure 4.5. The positive slope indicates that the grain yield and spikelet panicle^{-1} were directly correlated each other thus; due to the increasing of number of spikelet panicle-1also increased the grain yield.

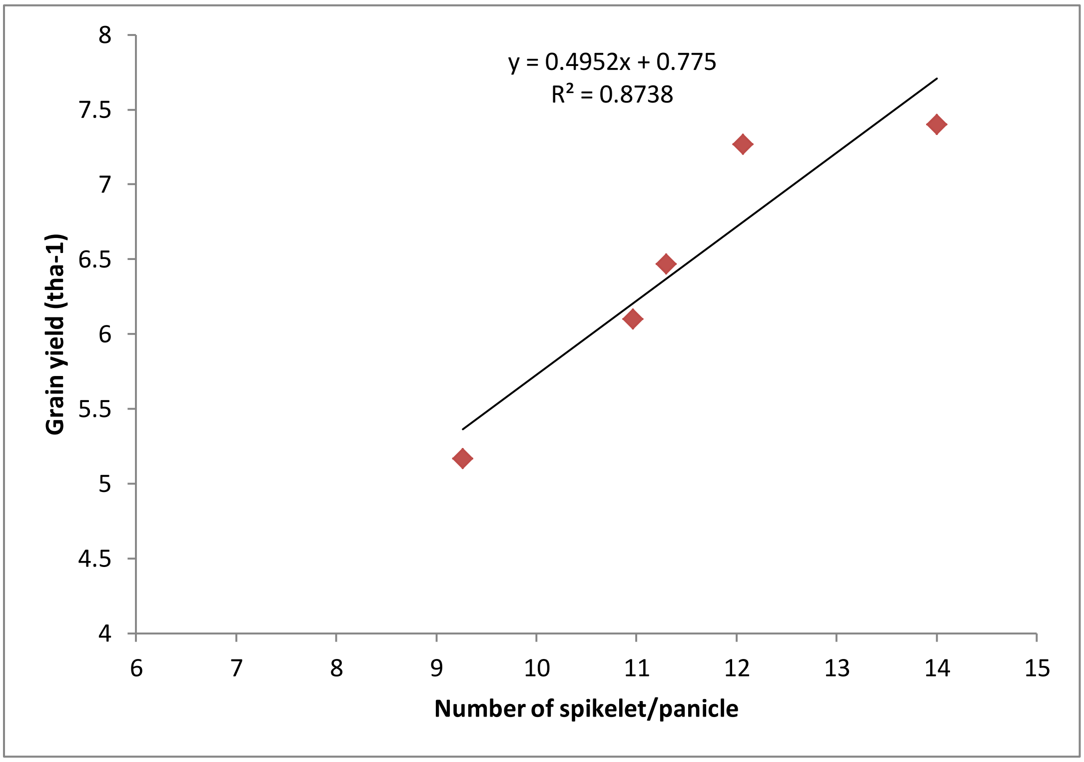

Figure 4.8 Relationship spikelet panicle^{-1} and grain yield of rice (BRRI dhan 29)

4.5.5 Grain yield and straw yield

The grain yield and straw yield relationship between these two parameters showed positive and significant correlation (Figure 4.5) the correlation co-efficient value of (r = 0.931). The line of regression X (straw yield) on Y (Grain yield) having Y= 0. 8395x-2.0303 revealing that the grain yield dependent on the character of straw yield, because the positive slope indicates that the grain yield and straw yield was directly correlated i.e. increasing in straw yield is an increased the grain yield of rice as well.

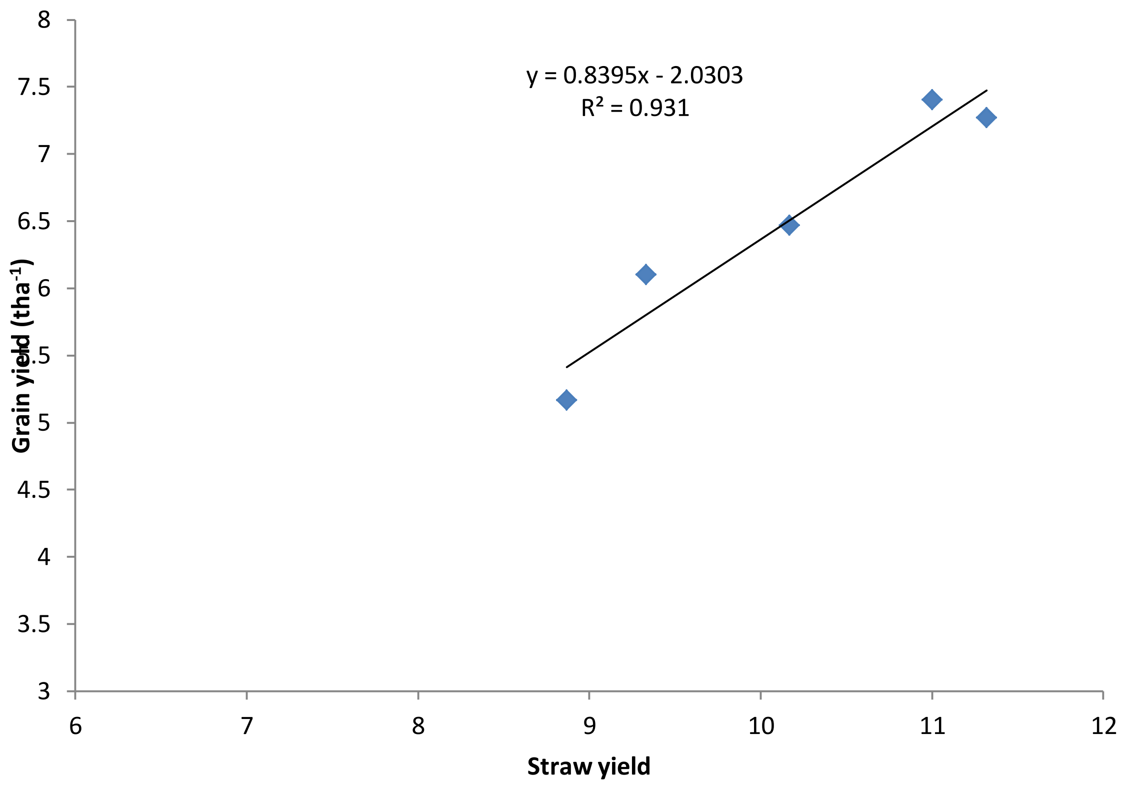

Figure 4.5 Relationship straw yield and grain yield of rice (BRRI dhan 29)

4.5.6 Grain yield and filled grain panicle^{-1}

The grain yield and filled grain panicle^{-1} relationship between these two parameters showed positive and significant correlation (Figure 4.5) the correlation co-efficient value of (r = 0.8669). The line of regression X (filled grain panicle^{-1}) on Y (Grain yield) having equation Y= 0. 044x-0.3193 revealing that the grain yield dependent on the character of straw yield, because the positive slope indicates that the grain yield and filled grain panicle^{-1} was directly correlated i.e. increasing in filled grain panicle^{-1}is an increased the grain yield of rice as well.

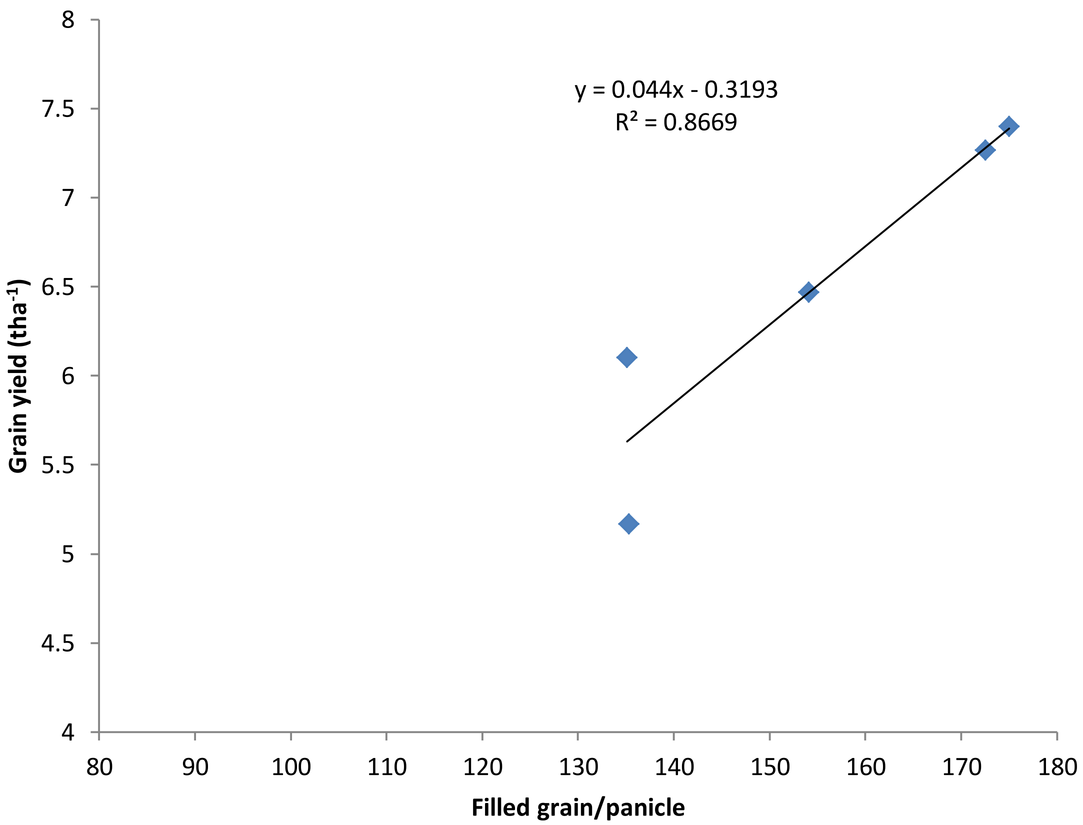

Figure 4.6 Relationship filled grain panicle^{-1} and grain yield of rice (BRRI dhan 29)

CHAPTER V

SUMMARY AND CONCLUSION

The present study was conducted in the research central field of Hajee Mohammad Danesh Science and Technology University (HSUT), Dinajpur. During the period from December, 2016 to April, 2017to evaluating the effects of vermicompost and inorganic fertilizer on the growth and yield of rice. The soil belongs to the AEZ of Old Himalayan Piedmont plain (AEZ 1). The soil is Ranishankail sandy loam in texture having pH 5.87, organic matter 1.719%, total N 0.085%, available P 14.60 ppm, exchangeable of K 0.20 meq and available S 1.36 ppm. There were five (5) treatments that were consisting of vermicompost and N, P K and S fertilizer in different doses. The treatment combinations include T_1 (Vermicompost 5 t ha^{-1}), T_2 (Vercompost 2.5 t ha^{-1}), T_3 (vermicompost 2.5 t ha^{-1}+ $^1/_2$N, P, K and S of recommended doses), T_4 (Vermicompost 2.5 ton ha^{-1}+$^1/_3$ N, P, K and S of recommended), T_5 (full doses of N, P, K and S). The experiment was laid out in Randomized Complete Block Design (RCBD) with a three replications.

The total number of unit plots was 15 plots. The size of the unit plot was 2.5m × 2m ($5m^2$) the spacing between blocks was 20 cm and plot to plot was 20cm. the samples of soils were collected before broadcasting and after harvest. Intercultural operations were done such as weeding, irrigation, insect and pest control, harvesting and threshing, collection of plant sample and procedure of data collection. The grain and straw samples were analyzed for N content. Initial and post-harvesting soil samples were analyzed for physical and chemical properties of soil.

All data were statistically analyzed by f-test and the mean differences were determined by Duncan's Multiple Range Test (DMRT). Data analysis was done by computer using MSTAT software the experiment's results are summarized below.

These results shown that the yield components such as plant height, number of tillers $hill^{-1}$, panicle length, grain $panicle^{-1}$, number of filled grains, number unfilled grains, weight of 1000 grains, grain yield, straw yield, biological yield. The highest plant was found in treatment T_1 (95 cm) which was statistical similar to the treatment T_5 (93.8 cm). The lowest plant height was observed in treatment T_4 (74.1 cm) that was nearly similar to the other treatments of T_2 and T_3 with the values of (87.5), (81.2). The highest panicle length of 24.7 cm was found in T_2 which were statistically identical with almost the treatments of T_1 and T_5.

The lowest panicle length of 20.9 cm was observed in $T_{4.}$ The treatment may be ranged in order of $T_5>T_1>T_2>T_3>T_4$ in the panicle length. The highest numbers of tillers (26) was found in T_1 (full does of N, P, K, S) that was statistically similar to the T_2 (25). Others have the similar value of T_3 21, $T_4$21 and T_5 20, respectively. The treatments may be ranged in the order of $T_1>T_2>T_3>T_4>T_5$. The highest number of spikelet hill^{-1} (14) that was found in T_2 which was statistical identical almost with T_3 (12.) the lowest number of spikelet (9) was found in T_5 which was also similar by T_4 and T_1 with the value of 11 to 11, respectively. The maximum result grain panicle^{-1} was obtained (175) in T_2 The effect of vermicompost on increasing the number of grains panicle^{-1} was more pronounced as compared to fertilizers. On the other hand, the minimum grain per panicle was observed (115) in T_4. The maximum number of filled grain panicle^{-1} (175) was obtained in T_2 which was statistically similar to the treatment T_1 (173). Also the minimum number of filled grain panicle-1 was observed in treatment T_4 (135) which were comparable to the treatment T_3 and T_5 with the values of 154 and 135, respectively. The highest Number of unfilled grain panicle^{-1} (33) was found in T_1. On the other hand, the lowest number of unfilled grain panicle^{-1} was observed in T_3 (20). The greatest weight of 1000 seeds (24.990 g) was found from $T_{4,}$ Whereas, the minimum weight of 1000 seeds (19.397 g) was observed fromT_5 The treatment T_2 was recorded the highest grain yield of (7.4 t ha^{-1}) which was statistically identical within T_1 of (7.3 t ha^{-1}), while the lowest grain yield was observed in T_5 (5.2 t ha^{-1}). The highest straw yield of 11.3 t ha^{-1} was obtained in T_1 and the lowest value of 8.9 t ha^{-1} was recorded in T_5 which was statistical comparable to the other treatments of T_4 and T_3 with the values of 9.3 and 10.2 t ha^{-1}. The maximum biological yield (18.7 t ha^{-1}) was recorded from T_2 which was statistically identical (18.4 t ha^{-1}) with T_1, whereas, the lowest biological yield (14 t ha^{-1}) was obtained from T_5 which was statistical similarly with T_3 of (15.3 t ha^{-1}).

The present study strongly agrees with the above results and it was concluded that the use of vermicompost will certainly enhance the yield of any crop besides enhancing the texture, color, taste and even of the agricultural product. The results suggested that the effects of vermicompost were more efficient than chemical fertilizers for the production of rice (BRRI dhan 29).

This research recommended show Vermicomposting is a new Technology, environmentally-friendly process used to treat organic waste. The resulting vermicompost has been shown to have several positive impacts on plant growth and health. This organic fertilizer is therefore increasingly considered in agriculture in as a promising alternative to inorganic fertilizers. By this the farmers can save money using vermicompost being able get more yield as well as economic solvency which have no health hazards and eco-friendly in national aspect.

The present study also reveals that application of vermicomost in cultivation of rice increased the rice production. The importance of vermicompost is to promote and increase the yield of rice (BRRI dhan 29), on the other hand it maintain the soil health and its ability to provide to the crops in nutrients and also improves the chemical properties of soil. The application of vermicompost reduced the amount of inorganic fertilizer to the rice and also extra cost, because vermicompost is cheap and available in rural area. Vermicompost produced same yield when compared to the inorganic fertilizer.

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APPENDIX

Appendix I: Monthly recorded air temperature, Relative Humidity and rainfall during January, 2017

Year	Monthly	Air Temperature (^0c)			Relative Humidity (%)	Rainfall (mm)
		Maximum	Minimum	Average		
2017	January	25	9.7		84	83
	February	27.32	15.33		74.18	
	March	29.96	19.73		73.74	
	April	32	24		73	
	May	31	28		71	

Source: Wheat Research Center, Nashipur, Dinajpur (2017)

APPENDIX II: Experimental sit (Map Dinajpur sadar Upazila Showing research Field)