EFFECTS OF POTASSIUM AND SULPHUR WITH VERMICOMPOST ON GROWTH AND YIELD OF BORO RICE (BRRI dhan81)

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECTS OF POTASSIUM AND SULPHUR WITH VERMICOMPOST ON GROWTH AND YIELD OF BORO RICE (BRRI dhan81)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE** embodies the result of a piece of *bona-fide* research work carried out by **SABIHA AZAD SHORMEE**, Registration No. **15-06499** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

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

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EFFECTS OF POTASSIUM AND SULPHUR WITH VERMICOMPOST ON GROWTH AND YIELD OF BORO RICE (BRRI dhan81)

ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka from November 2020 to May 2021 to investigate the effects of potassium and sulphur with vermicompost and to find out the best combination for better performances of Boro rice (BRRI dhan81). The experiment consisted two factors, Factor A: four potassium and sulphur fertilizer treatments viz: F_0: Control (no fertilizer), F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1} and Factor B: three vermicompost treatments viz: V_0: Control (no vermicompost), V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}. The experiment was laid out in randomized complete block design with three replications. Data were recorded on growth parameters, yield and yield components. The treatments had significant effects on most of the parameters. Results indicated that F_2, among the potassium and sulphur treatments and V_2, among the vermicompost treatments performed best in case of most growth and yield related characteristics like plant height, total number of tillers $hill^{-1}$, number of panicles $hill^{-1}$, panicle length, number of spikelets $panicle^{-1}$, number of filled spikelets $panicle^{-1}$, number of unfilled spikelets $panicle^{-1}$, 1000 grain weight, grain yield and straw yield. In case of treatment combinations the total number of tillers $hill^{-1}$ (17.9) and panicles $hill^{-1}$ (16.7) were received from F_2V_2. Again, F_2V_2 treatment combination also performed the best result in case of the panicle length (23.25 cm), number of filled spikelets $panicle^{-1}$ (126.41), total number of spikelets $panicle^{-1}$ (147.50) and 1000-grain weight (20.94 g). F_2V_2 treatment combination produced the highest grain and straw yield (6.60 t ha^{-1} and 8.74 t ha^{-1} respectively). On the contrary, control treatments performed the lowest in all the growth and yield related parameters. Finally, the treatment combination F_2V_2 which is 100 kg ha^{-1} potassium and 20 kg ha^{-1} sulphur with 4 t ha^{-1} vermicompost performed the best for increasing the yield of Boro rice and improved the nutrient status of post-harvest soil of AEZ 28.

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ABBREVIATIONS AND ACRONYMS

N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
S	:	Sulphur
DAT	:	Days after transplanting
ANOVA	:	Analysis of variance
LSD	:	Least significant difference
Df	:	Degrees of Freedom
C.V.%	;	Percentage of Coefficient of Variation
T	:	Ton
H	:	Hectare
pH	:	Potential hydrogen
Ppm	:	Parts per million
RCBD	:	Randomized complete blocked design
CEC	:	Cation exchange capacity
Meq	:	Milliequivalents
TSP	:	Tripple super phosphate
MoP	:	Murate of potash
Kg	:	Kilogram
G	:	Gram
Ml	:	Milliliter
L	:	Liter
M	:	Meter
Cm	:	Centimeter

CHAPTER I

INTRODUCTION

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereals of Bangladesh which occupies the first position as a staple food (Manzoor *et al.*, 2006). The demand for rice continues to increase owing to continued growth of population. But cultivable land of Bangladesh is decreasing day by day. Even those fields are yet cultivable; fertility is also decreasing drastically due to exhaustive cultivation. N, P, K, S are some of the major nutrients (Shah *et al*., 2008) that usually supplied by farmers as fertilizers while cultivation of rice. Balanced nutrition especially application of potassium and sulphur to the rice crop is one of the important inputs that can enhance productivity to a great extent. Nutrients are also supplied by indigenous sources such as soil minerals, soil organic matter, rice straw, manure, and water through rain or irrigation. In which crop residues are not returning to land now-a-days due to intensive use as animal feed and fuel. Soil organic matter can only be replenished in the short term by the application of organic matter such as vermicompost (Glaser *et al*., 2001). There is tendency to use indiscriminate amount of nitrogenous fertilizers and very limited amount of other nutrients containing high analysis chemical fertilizers (Rahman *et al.,* 2008). To ensure productivity balanced use of potassium and sulphur with other nutrient as well as maintaining the organic content of soil is very crucial for better rice yield.

Lack of potassium restricts the establishment, development, and yield of crops (Rengel and Damon, 2008). Potassium is required for the activity of many enzymes, including those of energy metabolism, protein synthesis, and solute transport. Also it contributes significantly to cell turgor, especially in rapidly expanding cells, and acts as a counter cation for anion accumulation and electrogenic transport processes (Amtmann *et al.*, 2006, White and Karley 2010). The potassium reserve of any soil is certainly limited, and intensive cropping and use of modern rice varieties for high yield caused heavy depletion of K in soils, particularly in the absence of potassium application (Tiwari, 1985). On the other hand sulphur has been also identified as a major nutritional problem for rice. Sulphur is involved in amino acid and protein synthesis, enzymatic and metabolic activities in plants, which account for approximately 90% of organic sulphur in the plant. When S becomes limiting, addition of N does not change the yield of rice. If it is limiting during early growth, then tiller number and therefore final yield will be reduced (Blair and Lefroy, 1987).

Organic matter is called the heart of soil and amendments of soil; by applying organic matter solely or in combination with inorganic fertilizers can be a biologically and economically viable approach to maximize rice yield sustainably along with a significant reduction in methane emission from rice fields (Baldock, and Nelson, 2000). 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. In addition, rapid mineralization of soil organic matter ocean due to humid tropic climatic conditions of Bangladesh. The continuous use of chemical fertilizers are decreasing crop productivity day by day and international community addresses increasing concern for sustainable agriculture through integrated and holistic approach to soil nutrient management (IRRI, 1991). Compared to other conventional organic manures, vermicompost contains large amounts of total nutrients with larger percentage of available forms. It also supplies high number of microorganisms and also considerable level of growth regulators such as auxins, gibberellins, cytokinins. Vermicompost application accelerates the ripening process of the crop with improving the quality parameters of cultivated plants (Kovacik, 2014). It is eco-friendly, non-toxic, consumes low energy input for composting and is a recycled biological product (Lourduraj and Yadav, 2005). They have a high and diverse microbial and enzymatic activity, fine particulate structure, good moisture-holding capacity, and contain nutrients such as N, P, K, Ca and Mg in forms readily taken up by plants (Prabha *et al*., 2005; Arancon and Edwards, 2009). Vermicompost is slow releasing organic fertilizer as a result nutrient loss is low and nutrients availability remains for longer period of time. Vermicompost also improves soil structure, increases aeraetion, and improves water holding capacity. Hidlago *et al*. (2006) reported that the incorporation of earthworm increased plant growth, leaf growth and root length. There is a good evidence that vermicompost promotes growth of plants and it has been found to have a favourable influence on all yield parameters of crops like, wheat, paddy, and sugarcane (Ansari, 2007). Rice produced by organic farming had higher grain quality (Mendoza, 2004).

The demand for organic food is gradually increasing both in developed and developing countries with an annual growth rate of 20–25 per cent (Ramesh *et al*., 2005). Therefore, 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 conjunction with inorganic fertilizers to obtain optimum yields (Rama Lakshmi *et al*., 2012). The organic and inorganic fertilizer has helped to sustain soil fertility and crop productivity in rice (Baldock and Nelson, 2000). Application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K by the plant, compared to chemical fertilizer alone (Bokhtiar and Sakurai, 2005). To get maximum yield combination of organic and inorganic fertilizer is considered to be an effective option.

Therefore, it is very important to investigate the effects of potassium and sulphur on growth and yield of rice and to find a proper dose. Thus the objectives of this study are,

1. To observe the effect of potassium and sulphur on growth and yield of Boro rice (BRRI dhan81).
2. To assess the effect of vermicompost on growth and yield of Boro rice (BRRI dhan81).

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Many research works were performed about the effects of potassium and sulphur with vermicompost on growth and yield of Boro rice (BRRI dhan81). Some of important and informative works have so far been done in home and abroad related to this experimentation have been presented in this chapter.

2.1 Effects of potassium on growth, yield and quality of rice

Wihardjaka *et al*. (2022) conducted a study to determine the effect of fertilizer management in light-textured rainfed rice fields on the K dynamic and lowland rice yields. Plant K uptake significantly increased with fertilizer application, where NPK fertilizer increased K uptake by 88.6% (DSR) and 71.9% (TPR). Exchangeable and nonexchangeable K in soil was generally high at 40 and 60 d after germination, and decreased in harvest time. The nonexchangeable K was generally higher than exchangeable K at 20, 40, 60, and 100 d after germination. The application of straw compost not only significantly increased grain yield, but also effectively provided K for plants in the form of exchangeable K and K slowly available K, so it was effectively used as an alternative supply of K to replace K from inorganic fertilizers.

Ojha *et al.* (2021) conducted a study to observe the limitation of K nutrient in the crops by establishing field trials from 2009–2014 at three agro-ecozones. Results revealed that an increase in K rates from 45 to 75 kg K_2O ha^{-1} under inner-Terai and Terai conditions and 45 to 60 kg ha^{-1} under high-Hills conditions produced significantly higher grain yields compared to the recommended K dose. Economically, the optimum rate of K fertilizer should not exceed 68 kg K_2O ha^{-1} for rice in all agro-ecozones, or 73 kg K_2O ha^{-1} for wheat in inner-Terai and 60 kg K_2O ha^{-1} for wheat in high-Hills and Terai. Our findings suggest to increase potassium application in between 1.5 to 2.5 times of the current K fertilizer rate in rice-wheat cropping system of Nepal that need to be tested further in different locations and crop varieties.

Atapattu *et al.* (2018) stated that length, breadth, true density and bulk density of rice grains were the highest with 37.5 kg MOP/ha applied at heading and harvested at 30–35 DAFF. Crude protein (6.24%) and crude fat (2.61%) contents in grains were the highest when harvested at 40 DAFF and 35–40 DAFF, respectively. Amylose content decreased with increased MOP rates at the time of heading and delayed paddy harvest. The highest average paddy yield (APY; 6.85 t/ha), head rice yield (HRY; 65%) and total rice milling yield (TMY; 67%) were recorded with 37.5 kg MOP/ha applied at heading of rice plant and paddy harvested at 35 DAFF. The APY, HRY and TMY were also 13.8, 7.7 and 5.9% higher, respectively, compared to the control. Applying K fertilizer at a rate 50% more (18.75 kg K/ha) than the recommended rate at the time of heading (7 WAP) and harvesting paddy at optimum maturity (35 DAFF), which is 5 days later than the recommendation, increase the yield and grain quality of direct seeded rice. Harvesting later than 35 DAFF resulted in a 10.5% loss of HRY ($P < 0.05$).

Islam and Muttaleb (2016) observed the effect of potassium (K) fertilization (0, 20, 40, 60, 80 and 100 kg K ha^{-1}) on yield, nitrogen (N) and K nutrition of Boro (dry season) rice and apparent soil K balance was studied. Results indicated that BRRI dhan29 maintained an average grain yield of 5.19 t ha^{-1} $year^{-1}$ without K fertilization. Potassium fertilization significantly increased the grain yield to 6.86 t ha^{-1} $year^{-1}$. Quadratic equations best explained the progressive increase of rice yield with increasing K rates. Optimum dose of K in 3 years ranged from 78 to 93 kg ha^{-1}. Internal N use efficiency of rice decreased with increasing K rates. However, K use efficiency was inconsistent. Apparent K balance study revealed that application of 100 kg K ha^{-1} was not able to maintain a positive K balance in soil under wetland ecosystem with Boro–Fallow–Fallow cropping system. However, K fertilization decreased the negativity of K balance in soil.

Islam *et al.* (2015) stated that. Plant height, panicle length, dry matter production at maturity, straw and grain yields significantly ($p < 0.01$) increased in a quadratic fashion; but tillers m^{-2}, panicles m^{-2}, spikelet $panicle^{-1}$, filled grains in a panicle, dry matter yield at panicle initiation (PI) stage increased significantly ($p < 0.01$) in a linear fashion when K rates were increased from 0 to 80 kg ha^{-1}. Maximum grain yield (4958 kg ha^{-1}) was obtained at 80 kg K ha^{-1}. Panicles m^{-2}, spikelets in a panicle, filled grains, dry matter yield, harvest index, 1000 grain weight had significant positive association with grain yield. Optimum K rate and K requirement of BRRI dhan49 was found to be 64.14 kg ha^{-1} 13 kg ha^{-1} rice. Calculated K dose for T. Aman rice was much higher than the recommended dose. Therefore, potassium dose for wet season rice should be increased for desired yield otherwise potassium mining from soil and yield reduction might be occurred.

Maryam and Ebrahim (2014) conducted this experiment to investigate the effect of nitrogen and potassium fertilizers on yield and yield components of a rice cultivar "Hashemi" as factorial laid out randomized complete block design with three replications at eastern Guilan (Amlash) during farming season 2013. The results of ANOVA revealed that the effect of potassium on height and the number of tiller was quite significant and it had significant effect on the number of filled grain. The interaction of nitrogen and potassium on height and the number of tiller was quite significant. Means comparison of data based on Duncan test for nitrogen showed that the fertilizer level of 90 kg ha^{-1} possessed the highest yield (5714 kg ha^{-1}). The highest number of tiller obtained at the fertilizer level of 90 kg ha^{-1} nitrogen with 526.7 tillers per m^{-2} and 150 kg ha^{-1} potassium with 438.8 tillers per m^{-2}. The highest number of tiller obtained when 90 kg ha^{-1} nitrogen with 150 kg ha^{-1} potassium and 90 kg ha-1 with 75 kg ha^{-1} potassium were applied to gain 578.3 and 546.7 tillers per m^{-2} , respectively.

Kumar *et al.* (2013) reported that the interaction effect of N and K was significant for number of grains $panicle^{-1}$, hollow grain percentage, biological yield and harvest index. Potassium application as top-dressing together with nitrogen increased potassium content of plant, grain number in panicle and straw yield f rice.

Wang (2011) conducted a field experiment to study the effects of N, P and K fertilizer application on grain yield, grain quality as well as nutrient uptake with four levels of nitrogen (N), phosphorus (P) and potassium (K) fertilizers. The results revealed that the application of N, P and K fertilizer significantly increased grain yield, and the highest yield was found under the combined application of N, P and K fertilizer.

Potassium is the most abundant nutrient in plants including rice plant. This is especially true for improved cultivars that uptake K considerably up to four-fold higher than native cultivars (Dobbermann *et al*. 1998; Bahmanyar and Mashaee 2010).

Li *et al*. (2009) observed that the number of tillers m^{-2}, 1000-grain weight, paddy and straw yield significantly increased with the application K with other fertilizer combinedapplication of K and N had a remarkable positive reciprocal effect on crops, and was an important approach in improving K use efficiency.

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

Natarajan *et al*. (2005) conducted an experiment during 2002-2003 with two rice hybrids, KRH2 and DRRHI in main plots and three levels of potassium (0, 40, and 80 kg ha^{-1}) in subplots to study the performance of rice hybrids with different K levels. The results clearly indicated that hybrid KRH_2 performed superior with different levels of K.

Qiangsheng *et al.* (2004) reported that K uptake by rice population is maximized in the growth season of elongation stage to heading stage.

In fact continuous application of K improves all soil properties and perhaps the use of higher rates of nitrogen, application of 135kg potassium along with nitrogen has become very necessary due to intensified agriculture with high-yielding varieties (Meena *et al.* 2002).

Sarkar and Singh (2002) conducted a field experiment to determine the effect of potassium and sulphur. They applied 110 kg N: 90 kg P: 70 kg K: 20 Kg S ha^{-1}.

Ranjha *et al.* (2001) conducted a pot study to see the relative effect of SOP and MOP on rice growth in sandy clay loam soil used @ 10 kg pot^{-1}. Potassium was applied @ 0, 100, 200, 300, 400 and 500 mg kg^{-1} soil each from MOP and SOP along with basal dose of N + P @ 150 and 100 kg ha^{-1}. Plant height, number of tillers pot^{-1}, paddy yield, 1000-grain weight and straw yield remained unaffected by both the sources of potassium. Nitrogen and potassium contents of rice paddy and straw were unaffected by all the treatments. However, significant increase in P contents of rice straw was noted where SOP was applied. Sulfur contents in both grain and straw increased significantly with increasing SOP rates while Cl- contents increased with increasing MOP rates. There was gradual decrease in Cl- concentration at panicle emergence, straw and paddy as compared to first sampling (35 days after transplanting)

The crop of rice is generally fertilized by farmers either with nitrogen or with nitrogen and phosphorus only, though potassium is equally important as it stabilizes yield. Potassium plays an important role in ensuring efficient utilization of nitrogen (Singh and Singh 2000).

2.2 Effects of sulphur fertilization on growth, yield and quality of rice

Jena and Kabi (2012) observed the effect of gromorbentonite S pastilles and gypsum on yield and nutrient uptake by hybrid rice-potato-green gram cropping system. Application of S significantly increased the grain and straw yield, nutrient uptake by hybrid ricepotato-green gram cropping system. A dose of 60 kg S ha^{-1} through S-bentonite pastilles increased the yield of hybrid rice, potato and green gram over control by 34, 21 and 18 percent, respectively.

Rasavel and Ravichandran (2012) conducted field experiments to study the interaction of phosphorus, sulfur and zinc on growth and yield of rice in neutral and alkali soils. The results revealed significant interactions among P, S and Zn on growth and yield of rice. The highest plant height (52.8 cm), number of tillers hill-1 (16.3), LAI (5.12), panicle length (21.6 cm) and number of grain $panicle^{-1}$ (108.3) was noticed with application of 20 kg S ha^{-1} + 10 kg Zn ha^{-1} (T8) in alkali soils respectively. The highest grain (4678 6 kg ha^{-1}) and straw yields (5642 kg ha^{-1}) was noticed with application of 20 kg S + 10 kg Zn ha^{-1} in alkali soils.

Devi *et al.* (2012) studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The study revealed that yield attributing characters like number of branches per plant, pods per plant and 100 seed weight and yield were increased with the application of sulphur and boron as compare to control. The overall result revealed that application of 30 kg sulphur per hectare and 1.5 kg boron per hectare were found to be the optimum levels of sulphur and boron for obtaining maximum yield attributes, yield, oil and protein content, total uptake of sulphur and boron, net return, cost and benefit ratio of soybean under upland condition as compare to other levels of sulphur and boron respectively.

Singh *et al*. (2012) conducted a field experiment to evolve suitable nutrient management system with respect to one secondary nutrient (sulphur) and one micronutrient (zinc) in rice for Indo- Gangetic plains of Bihar at ICAR Research Complex for Eastern Region Patna during 2008-09. Application of sulphur at 20 kg

ha^{-1} produced significantly taller plants over no application of sulphur at all the growth stages. Plots received 20 kg sulphur produces significantly higher LAI over no application and produced at par with other tested levels of sulphur in most of the phenological stages. Yield attributes were also influenced significantly with graded doses of sulphur. In case of sulphur, application at 20 kg ha^{-1} produced rice grain 7.25 t ha^{-1} significantly over control. Harvest index (HI) was not influenced significantly by any of tested factors.

Bhuiyan *et al.* (2011) investigated the integrated use of organic and inorganic fertilizers on the yield of T. Aus and mungbean in a Wheat-T. Aus/mungbean-T. Aman cropping sequence at the Bangladesh Agricultural University Farm, Mymensingh. The rates of N, P, K and S for T. Aus rice were 60, 12, 32 and 5 kg ha^{-1} for MYG, and 90, 18, 48 and 7.5 kg ha^{-1} for HYG, respectively. The variety BR 26 for T. Aus rice was planted in all three years. The results showed that grain yields (3.46 t ha^{-1}) and straw yields (5.19 t ha^{-1}) of T. Aus rice (mean of three years) was increased significantly by the application of 7 fertilizers. The application of chemical fertilizers, NPKS (HYG) remarkably increased the crop yields while the lowest mean grain yields of 1.48 t ha^{-1} for T. Aus and 0.42 t ha^{-1} for mungbean were recorded in the unfertilized control plots.

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

Jawahar and Vaiyapuri (2010) carried out a field experiment at Experimental Farm, Annamalai University, Annamalai Nagar, Tamil Nadu, India during 2007-2008 to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. Among the different levels of sulphur, application of 45 kg S ha^{-1} recorded maximum grain and straw yield of rice, which was closely followed by 30 kg S ha^{-1}. This treatment recorded 18.12, 7.47 and 2.43 per cent increase over 0, 15 and 30 kg S ha^{-1}.

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

Rahman *et al.* (2009) studied the effect of different levels of sulphur on growth and yield of BRRI dhan41 at Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh during T. Aman season of 2007. All yield contributing characters like effective tillers hill^{-1}, filled grain panicle^{-1}, grain yield, straw yield, biological yield and 1000-grain weight except plant height and panicle length of BRRI dhan41 significantly responded to different levels of applied S.

Islam *et al.* (2009) conducted an experiment at the Department of Soil Science of Bangladesh Agricultural University (BAU), Mymensingh during T. Aman season of 2006 to evaluate the effects of different rates and sources of sulphur on the yield, yield components, nutrient content and nutrient uptake of rice (cv. BRRI dhan30). The grain and straw yields as well as the other yield contributing characters like effective tillers hill^{-1}, panicle length, filled grains panicle^{-1} and 1000 grain weight were significantly influenced due to application of sulphur. The highest grain yield of 5293 kg ha^{-1} and straw yield of 6380 kg ha^{-1} were obtained from 16 kg S ha^{-1} applied as gypsum. The lowest grain yield (4200 kg ha^{-1}) and straw yield (4963 kg ha^{-1}) were recorded with S control treatment. The overall results suggest that application of sulphur @ 16 kg S ha^{-1} as gypsum was the best treatment for obtaining higher grain yield as well as straw yield of T. Aman rice.

Mrinal and Sharma (2008) worked out a field trials during the rainy (kharif) season of 2002 and 2003 to evaluate the relative efficiency of different sources of sulphur (gypsum, elemental sulphur and cosavet) and different levels of sulphur (0, 10, 20, 30 and 40 kg S ha^{-1}) in rice. Sulphur application maximized the growth and yield contributing characters of rice. The increasing sulphur levels up to 30 kg S ha^{-1} significantly enhanced grain and straw yields of rice.

Oo *et al.* (2007) was carried out a field experiment to assess the effect of N and S levels on the productivity and nutrient uptake of aromatic rice. They found that 100 kg N ha^{-1} and 20 kg S ha^{-1} for increased productivity of aromatic rice and uptake of N, P. 11 K and S under transplanted puddled conditions.

Bhuvaneswari *et al.* (2007) stated a field experiments during the 2001 kharif season, to find the effect of sulphur (5) at varying rates, i.e. 0, 20,40 and 60 kg ha^{-1}, with different organics, i.e. green manure, farmyard manure, sulfitation press mud and lignite fly ash, each applied at 12.5 tha^{-1}, on yield, S use efficiency. The results observed that rice significantly showed to the S application and organics compared to the control. It was observed that 40 kg S ha^{-1} produced the maximum grain (5065 kg ha^{-1}) and straw yields (7524 kg ha^{-1}).

Rahman *et al.* (2007) conducted a field experiment on a non-calcareous dark gray floodplain soil (Sonatola series) of BAU farm, Mymensingh during Boro season of 2004 using rice (cv. BRRI dhan29) as a test crop. All plots received an equal dose of N, P, K and Zn. The application of S had a significant positive effect on tillers hill-1plant height, panicle length and grains $panicle^{1}$. The highest grain (5.81 t ha^{-1}), and straw (7.38 t ha^{-1}) yields were recorded in 20 kg S ha^{-1}. The control had the lowest grain yield of 4.38 t ha^{1} as well as the lowest straw yield of 5.43 t ha^{1}. Regression analysis showed that the optimum dose of S was 32.89 kg ha-1 and the economic dose of S was 31.59 kg ha^{-1} for maximizing the yield.

Alamdari *et al.* (2007) treated a field experiments to evaluate the influence of sulphur (5) and sulphate fertilizers on zinc (Zn) and copper (Cu) by rice. The highest Cu content in the leaves was obtained when N, P, K, S and Cu sulphate were applied compared to the control. But, both Zn and Cu contents in the grain enhanced when N. P, K, S and Zn, Cu and Mn sulphate were applied together.

Islam *et al.* (2006) conducted an experiment in Bangladesh to find the effect of gypsum (100 kg ha^{-1}) applied before planting, and at 30 and 60 days after planting, on the nutrient content of transplanted Aus rice (BR-2) in the presence of basal doses of N, P. K fertilizers from May to September 1996. A control without gypsum application was included. Gypsum application at various dates increased progressively all the nutrients such as N, P. K, S, Ca and Mg. When the gypsum was applied at 30 days after planting resulted the maximum increase of N, P, K, S. Ca and Mg. Protein synthesis was much higher due to gypsum application at 30 days after planting and accelerated with all the treatments of gypsum.

Singh *et al.* (2005) performed a field experiment during the kharif season on an Inceptisol in Varanasi, Uttar Pradesh, India, to study the effect of S and Mn fertilizer application on the content and quality of bran oil of different rice cultivars, viz. Pant-12 (short duration), Swarna (long duration) and Malviya-36 (medium duration). The treatments comprised S and Mn applied at 0, 25, 50 and 0, 10, 20 kg ha^{-1} through gypsum and $MnCl_2$, respectively, and their combinations. A uniform application of recommended doses of N, P and K was given in all the experimental plots. Application of both S and Mn significantly enhanced the bran content and yield of rice over the control. The highest dose of Mn and S on an average caused an increase of 15.2 and 45.0% in bran oil yield over the control, respectively. Increasing levels of S broughtabout noticeable increment in the percentage of unsaturated fatty acids, including PUFA indicating improvement in the quality of bran oil.

Biswas *et al.* (2004) noticed the effect of S in different region of India. The optimum S rate varied between 30-45 kg ha^{-1}. Rice yields enhanced from 5 to 51%.

Chandel *et al.* (2003) treated a field experiment to determine the effect of sulphur nutrition and sulphur content on the growth of rice with 4 sulphur levels (0, 15, 30 and 45 kg ha^{-1}). Leaf area index, number of tillers, dry matter production, harvest index increased significantly with increasing S levels up to 45 kg S ha^{-1}.

Peng *et al.* (2002) observed a field experiment where the available S content was average in these soil samples was 21.7 mg kg^{-1}. The soil with available S content was 10 not higher than the critical value of 16 mg kg^{-1} accounted for 57.8%. Field experiments resulted that the application of S at the doses of 20-60 kg ha^{-1} was given yield-increasing efficiency to rice plant.

Sen *et al*. (2002) reported an extensive study on sulphur fertilizer application through single super phosphate in a sulphur deficient area of Murshidabad district, in India, in a rice-mustard cropping sequence. The yield of rice increased significantly with application of sulphur at 30 kg ha^{-1} and its residual effect on mustard was resulted. Application of sulphur not only helped to increase yield in both crops but also helped to control the movement and distribution of various cationic micronutrients in both the crops.

Singh and Singh (2002) observed a field experiment to find the effect of various nitrogen levels (50, 100 and 150 kg ha^{-1}) and S levels (0, 20 and 40 kg ha^{-1}) on rice cv. Swarna and PR-IOS in Varanasi, Uttar Pradesh. India. They stated that increasing levels of N and S up to 150 kg N ha^{-1} and 40 kg S ha^{-1} respectively significantly maximize plant height, tiller number m^{-2} row length, production of dry matter, length of panicle and grains $panicle^{-1}$. They also showed that total N uptake, grain, straw and grain protein yields improved significantly with the increasing level of N and S application being the highest at 150 kg N ha^{-1} and 40 kg S ha^{-1} respectively.

Sarfaraz *et al.* (2002) carried out a field experiment to determine the effect of different S fertilizers at 20 kg ha^{-1} on crop yield and composition of rice cv. Shaheen Basmati in Pakistan. They found that the number of tillers m^{-2}, 1000-grain weight, grain, and straw yield were significantly increased with the application of NPK and S fertilizer compared to the control.

Nad *et al.* (2001) noticed that gypsum and ammonium sulphate as compared to elemental sulphur or pyrite, maintained sufficient N to S ratio in rice, resulting in decreasing in the unfilled grain percent, a vital consideration in rice yield.

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

Mandal *et al.* (2000) worked out a greenhouse experiment to assess the effect of N and S fertilizer on nutrient content of rice grain (BRRI dhan28) at different growth stages (tillering, flowering and harvesting). Sulphur was applied as gypsum at 0, 5, 10 and 20 kg S ha^{-1} and nitrogen as urea. The straw and grain yield of rice increased significantly with combined application of urea and gypsum at different doses.

2.3 Effects of Vermicompost on crop production

Fong *et al.* (2022) stated that vermicompost is enriched with plant essential nutrients and has been shown to suppress the incidence of pests; however, its potential is affected by its food sources. Earthworms were fed cabbage or pig manure to produce two vermicomposts enriched in sulfur and nutrients, respectively. A pot experiment and a feeding experiment were then conducted by them to determine whether the application of the vermicomposts and sulfur could increase soil fertility, promote the growth of *Brassica chinensis* L., and inhibit the growth of *Spodoptera litura Fabricius* larvae. The characteristics of the vermicomposts were mainly affected by the food sources, and vermicomposted cabbage was found to have higher sulfur content than vermicomposted pig manure. The application of the vermicomposts enhanced the concentrations of organic matter and available phosphorus, as well as the exchange concentrations of potassium, cadmium, and magnesium in the soil. Moreover, the growth of and the accumulated phosphorus and sulfur in the *B. chinensis* L. samples significantly increased when the plants were grown in soils treated with the two vermicomposts. Hence, the addition of vermicomposted cabbage and sulfur fertilizers can decrease the relative growth rate, total consumption, efficiency of conversion of ingested food, and relative consumption rate of *S. litura* larvae, possibly due to the increase in leaf sulfur concentration.

Gupta and Dahiya (2021) stated that vermicomposting is easy, cost effective and enriches soil with nutrients as well as microbes. So, vermicomposting of rice straw can be a better substitute of chemical fertilizers. They described requirements, steps, nutrient content and effect of vermicompost prepared from rice straw on plant growth.

An experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka from November 2018 to May 2019 by Ashadul (2019). The result showed that 75% NPK as NPK briquettes + 25% NPK from vermicompost performed best in case of all of the vegetative (Plant height, number of tillers, number of effective and ineffective tillers and panicle length) and reproductive characteristics (days to panicle initiation, no of grain panicle^{-1}, no of filled and unfilled grain panicle^{-1} and 1000 grain weight). Maximum grain yield (6.7 t ha^{-1}) as well as straw yield (7.1 t ha^{-1}) was obtained from 75% NPK as NPK briquettes + 25% NPK from vermicompost. Harvest Index (48.9 %).was also the maximum for this treatment.

Kheyri (2017) stated that Vermicompost can be used as a soil additive on farmland to decrease chemical fertilizers consumption due to being able to provide plants with nutrients, increase soil cation exchange capacity, and improve soil water holding capacity. He performed a research was performed to investigate the effects of rate and split application time of vermicompost on yield and some agronomic traits of Tarom Hashemi rice cultivar. Treatments included rates of vermicompost application in four levels (0, 5, 10 and 15 ton.ha^{-1}). The results showed that the effect of different rates of vermicompost was significant on all the agronomic traits and grain yield. The effect of split application of vermicompost was significant on the measured traits except for the panicle length, 1000-grain weight and harvest index. Also, the interaction effect of the treatments was not found to be significant on the agronomic traits and grain yield. The greatest average grain yields (3790 and 3868 kg.ha-1) were obtained from vermicompost application rates of 10 and 15 ton.ha^{-1}, respectively. This has been attributed to the role of vermicompost in improving soil structure and enhancing soil physical and biological properties, which, in turn, result in increased nutrient availability in the soil during different vegetative and reproductive stages of plant growth (Afsharmanesh *et al.,* 2016). No application of vermicompost resulted in the lowest biological yield (5743 kg. ha^{-1}). Increasing vermicompost rate to 10 and 15 ton ha^{-1} raised rice biological yield by 26 and 27%, respectively.

Radzi (2017) stated that use of organic fertilizers is a good alternative to reduce the use of chemical fertilizer and solutions for maintaining soil fertility and achieving sustainable agriculture. Conducting a study they investigated the effects of different doses of vermicompost organic fertilizer on the growth and yield of rice MR219. The experimental treatments were arranged in Complete Randomized Design including four vermicompost application levels. The results indicated that the combined application of NPK fertilizer and organic fertilizer vermicompost had significant effects on growth parameter for plant height, number of leaves, number of tiller, fresh and dry weight. The plant applied with 70% vermicompost and 30% NPK shows the higher means for plant height and number of leaves. The plant applied with 50% vermicompost and 50% NPK shows higher means number of tiller, fresh weight and dry weight than other treatment. The maximum mean of yield recorded by the treatment of 70% vermicompost and 30% NPK fertilizer, but there is no significant difference between the treatments. Thus it was concluded that the application of vermicompost organic fertilizer, can be reduced chemical fertilizer urea up to 70 percent.

Sudhakar (2016) conducted at Annamalai University, Experimental Farm, Annamalainagar, Chidambaram during two seasons to identify and evaluate different sources of vermicomposts on productivity enhancement, nutrient uptake and nitrogen use efficiency in low land rice under SRI method of cultivation The experiment comprised of eight treatments which includes recommend dose of fertilizer alone and in combination with vermicomposts prepared from various organic wastes namely Paddy straw, Coirpith, sewage sludge, Sugarcane trash, Pressmud and Crop residues @ 5t ha^{-1}. These were laid out in randomized block design and replicated thrice. Rice cultivar ADT 36 was used as the test variety. The results revealed that crop raised with pressmud based vermicompost registered higher grain, straw yield and harvest index. The vermicompost treatments had significant influence on the nutrient uptake, Nitrogen use efficiency (NUE) and Economic nitrogen use efficiency (ENUE) over control and recommended dose of fertilizer by the crop at harvest. Among the different organic source of vermicompost, pressmud based vermicompost registered the highest N, P, K uptake, nitrogen use efficiency (NUE) and economic nitrogen use efficiency (ENUE) values at harvest. From the above experimental results, it could be concluded that with application of pressmud based vermicompost @ 5.0 t ha^{-1} not only resulted in higher yields but also superior in respect of nutrient uptake and nitrogen economy under SRI method of rice cultivation.

The importance of composts as a source of humus and nutrients to increase the fertility of soil and growth of plant has been well recognized in the present study. Vermicompost and chemical fertilizer were taken first for chemical analysis and then to find the effect of these composts on the growth of SRI Rice Cultivation. It was found that the vermicompost was rich in nutrients like Potassium, Nitrate, Sodium, Calcium, Magnesium, and Chloride and have the potential for improving plant growth than Fertilizer. The optimal growth of SRI Rice in our study conducted for a period of four month. The study also showed distinct differences between vermicompost and chemical fertilizer in terms of their nutrient content and their effect on SRI Rice plant growth (Kandan and Subbulakshmi, 2015)

Sultana *et al*. (2015) conducted an experiment to assess the effect of integrated use of vermicompost, pressmud and urea on the nutrient status of grain and straw of rice (Hybrid Dhan Hira 2). The highest amount of nitrogen (1.092%), phosphorus (0.297 %), potassium (0.374 %) in grain and the highest amount of potassium (1.213%), sulfur (0.091%) in straw were observed in plants receiving 90 kg N/ha from urea along with 30 kg N/ha from vermicompost. The highest sulfur (0.124 %) content in grain and the highest nitrogen (0.742%), the highest phosphorus (0.182 %) in straw was recorded in treatment 120 kg N/ha from urea. The highest amount of nitrogen (93.81 kg/ha), phosphorus (26.07 kg/ha), potassium (32.82 kg/ha) and sulfur (10.79 kg/ha) uptake by grains and the highest amount of nitrogen (55.70 kg/ha), phosphorus (13.79 kg/ha), potassium (92.43 kg/ha) and sulfur (6.91 kg/ha) uptake by straw of rice were observed in T_3 treatment. On the other hand the lowest values of these parameters were obtained from control treatment.

Dekhane, *et al.* 2014) conducted a trial with three replications and six treatments was laid out in Randomized Block Design to assess the performance of different organic and inorganic fertilizer on growth and yield of paddy crop (Variety GR 11) during Kharif season. Application of 50 % N through RDF + 50% N through vermicompost recorded higher growth attributes like plant height was 42.2 cm and 118.1 cm, no. of tillers per plant was 8.7 and 12.1 at 45 DAT and at harvest time respectively, panicle length (22.3 cm), grains panicle^{-1} (128.0), 1000-grain weight (19.7 g) and grain yield (4.97 t/ha.) and straw yield (5.77 t/ha.) of rice variety GR 11. The data clearly revealed that the yield obtained with treatment T5 (50% RDF + 50% N through vermicompost) was recorded significantly higher growth as well as yield attributes.

Bejbaruah *et al.*, (2013) conducted a study aimed to test whether nitrogen use efficiency (NUE) and crop yield can be enhanced by split application of vermicompost. Split application of vermicompost resulted higher yield parameters such as panicles (294 m^{-2}), filled grains panicle^{-1} (138), and total spikelets panicle^{-1} (142), grain yield (3.91 t ha^{-1}), and NUE, but only if vermicompost was applied at two or three doses. Higher availability of nitrogen (N) in soil with split applications coincides with higher NUE, and thus, split application not promoted N losses. Split application of vermicompost enhances the sustainability of rice cropping system.

Tharmaraj *et al.* (2011) studied the effect of vermicompost on soil chemical and physical properties was evaluated during samba rice cultivation studies. The physical properties such as, electrical conductivity (EC), porosity, moisture content, water holding capacity and chemical properties like nitrogen, phosphorous, potassium, calcium and magnesium were found distinctly enhanced in vermicompost treated soil, whereas the corresponding physicochemical values in control were minimum. The soil treated with vermicompost had significantly more electrical conductivity in comparison to unamended pots. The addition of vermicompost in soil resulted in decrease of soil pH. The physical properties such as water holding capacity, moisture content and porosity in soil amended with vermicompost were improved. The vermiproduct treated plants exhibit faster and higher growth rate and productivity than the control plants. Among the treated group, the growth rate was high in the mixture of vermicompost and vermiwash treated plants, than the vermicompost and vermiwash un-treated plants. The maximum range of some plant parameter's like number of leaves, leaf length, height of the plants and root length of plant, were recorded in the mixture of vermicompost and vermiwash. The results of this experiment revealed that addition of vemicompost had significant positive effects on the soil physical, chemical properties and plant growth parameters. Conjuctive use of vermicompost @ 2 t/ha along with 50 per cent N/ha enabled hybrid rice to produce grain yield at par that obtained by application of recommended dose of fertilizer along (Upendrarao and Srinivasulureddy, 2004).

Banik *et al.*, (2004) Grain yield and nutrient uptake by rice increased significantly with 100% fertilizer application (60 kg N + 17.5 kg P + 33.3 kg K) as well as with the combination of organic and inorganic fertilizers. Grain yield was maximum in both the years with 60, 17.5 and 33.3 kg/ha N, P and K, respectively, applied through fertilizers (4.12 and 5.57 tonnes/ha in 1999 and 2000), followed by treatment with 15 kg N replaced by vermicompost yielding 4.06 and 5.31 tonnes/ha in respective years. At the end of a 2-year cycle, the soil-available N, P and K status was not only found significantly higher than the control under fertilizer NPK alone but also in the combination of chemical fertilizers and organic manure-treated plots showing sustained fertility. The gross and net returns were significantly higher in treatment of 60 kg N + 17.5 kg P + 33.3 kg K that were statistically at par with treatment of 15 kg N through farmyard manure + 45 kg N (inorganic) + 13 kg P + 25 kg K.

A field experiment was carried out during wet season to study the response of scented rice (cv. Pusa basmati1) to levels of NPK, vermicompost and growth regulator at ARS, Siraguppa. The results revealed that application of 150:75:75 NPK kg ha^{-1} has recorded significantly higher growth, yield attributes and yield (5261 kg ha^{-1}) as compared to lower levels of NPK. Scented rice Pusa Basmati-1 responded significantly to the organic manure. Application of vermicompost @ 5 t ha^{-1} resulted in significantly higher yield (4889 kg ha^{-1}) as compared to no vermicompost application. Significantly response was observed from spraying of triacontanol (GR) @ 500 ml ha^{-1} with respect to growth, yield attributes and yield (4861 kg ha^{-1}) as compared to spraying @ 250 ml ha^{-1} and water spray (Murali and Setty, 2004).

Vermicomposting is the bioconversion of organic waste materials into nutritious compost by earthworm activity and is an important component of organic farming package. Meena (2003) reported multifarious effects of vermicompost on growth and yield of crops.

Unlike other organic manures, vermicompost addition has got the added advantage of quick nutrient absorption by plants, to result in better dry matter accumulation. The increase in panicle number per m2 noted in the study was due to the promotion of tiller production with the supply of vermicompost (Sudha and Chandini, 2003). Application of vermicompost improved the chemical and physical structures of the soil. (Anitha and Prema, 2003).

Earthworms can live in decaying organic wastes and can degrade it into fine particulate materials, which are rich in nutrients. Vermicomposting is the application of earthworm in producing vermin-fertilizer, which helps in the maintenance of better environment and results in sustainable agriculture, earthworm make the soil porous and help in better aeration and water infiltration. Vermicompost can be prepared from different organic materials like sugarcane trash, coir pith, pressmud, weeds, cattle dung, bio digested slurry etc. Increased availability of nutrients in vermicompost compared to non-ingested soil resulted in significantly better growth and yield of rice has been reported by several workers (Sudhakar, *et al.*, 2002).

Application of vermicompost with fertilizer N and bio-fertilizer increased the rice yield by 16 per cent over the application of fertilizer N alone. Vermicompost applied with FYM recorded higher grain and straw yield of rice (Jeyabal and Kuppuswamy, 2001).

2.4 Effects of inorganic and organic fertilizers application on crop production

Kumar *et al.* (2021) conducted a study to observe long-term influence of four fertility levels and organic and inorganic sulphur under rice-wheat cropping system on soil fertility build-up and the yields of crops. stated that increasing fertility levels significantly augmented crop yields; total and available S content in the soil and S uptake by crops under rice-wheat cropping system. The higher fertility levels were associated with higher grain and straw yields of rice and wheat than those of lower fertility levels. Influence of different organics on grain and straw yields varied in the order: Compost + crop residue > compost > crop residue > no organics. Sulphur uptake by rice and wheat increased from 3.5 to 15.9 and 2.0 to 14.8 kg ha^{-1}, respectively with increasing levels of NPKS. The sulphur uptake by these crops was in the order: Compost + crop residue > compost > crop residues > no organics. Accumulation of available and total S in soil was higher under inorganic-S-treated soil. Movement of sulphur down the depth was more from surface soil treated with organic S but at the same time it restricted the downward movement up to only 45 cm in the organic-manure- and crop-residue-treated soils.

Islam (2020) conducted a field experiment at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during March, 2019 to July, 2019 in aus rice season with a view to study the growth and yield variations in aus rice as influenced by integrated fertilization. The treatments consist of seven fertilization levels as T_1= 100% RDF (Recommended dose of fertilizers) (148 kg N ha^{-1} + 52 kg P ha^{-1} + 74 kg K ha^{-1}), T_2= Poultry manure (10 t ha^{-1}), T_3= Vermicompost (4 t ha^{-1}), T_4= Compost (5 t ha^{-1}), T_5= Poultry manure @ 10 t ha^{-1} + 50% RDF, T_6= Vermicompost @ 4 t ha^{-1} + 50% RDF, T_7 = Compost @ 5 t ha^{-1} + 50% RDF.. Results revealed that treatment T_5 gave significantly highest grain yield. T_5 registered significantly maximum total tillers $hill^{-1}$ (21.04), leaves $hill^{-1}$ (95.57), above ground weight $plant^{-1}$ (48.11 g), effective tillers $hill^{-1}$ (20.00), longest panicle (27.94 cm), highest filled grains $panicle^{-1}$ (139.67), 1000 grain weight (26.37 g), grain yield (4.88 t ha^{-1}), straw yield (5.93 t ha^{-1}) and biological yield (10.81 t ha^{-1}).

Kamal (2020) conducted a study in the experimental field of Sher-e-Bangla Agricultural University to assess effects of vermicompost and nitrogenous fertilizer on yield and grain quality of aromatic rice. This experiment consisted of two factors: Factor A: T_1: 100% N through urea, T_2: 90% N through urea + 10% N through vermicompost, T_3: 80% N through urea + 20% N through vermicompost, T_4: 70% N through urea+30% N through vermicompost, T_5: 60% N through urea + 40% N through vermicompost. Among the treatment combinations, the highest number of effective tillers $hill^{-1}$ (14.81), grain yield (4.94 t ha^{-1}), protein content (12.29%), amylose content (24.32%), was found from 60% N through urea + 40% N through vermicompost.

Mahmud *et al.* (2016) studied the combined effect of vermicompost and chemical fertilizers on the nutrient content in grain, straw and post harvest soil of boro rice cv.

BRRI dhan29, a field experiment was conducted in December, 2013 to June, 2014 at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Sixteen combinations of 4 vermicompost level @ 0, 1, 2, 4 t ha $^{-1}$ and 4 NPKS levels i.e. 0-0-0-0, 50-8-33-6, 100-16-66-12, 150-24-99-18 kg ha^{-1}, respectively were applied. Results showed that the highest dose of vermicompost and chemical fertilizer increased the concentration of P, K and S by rice grain and straw significantly at the harvesting stage. Combined application of vermicompost and chemical fertilizer failed to increase the total N content of post-harvest soil. Combination of vermicompost and chemical fertilizers also increased the organic matter, P, K and S status of post-harvest soil significantly.

Kumar *et al*. (2014) carried out during kharif season of 2011 to study the effect of organic and inorganic sources of nutrient on yield, yield attributes and nutrient uptake of rice cv. PRH-10. Application of organic and inorganic sources of nutrient in combination remarkably increased yield, yield attributes and16 nutrient uptake of rice than alone. 125% RDF + 5 t/ha vermicompost recorded significantly higher yield, yield attributes and nutrient uptake in comparison to other treatments and this was followed by 100% RDF + 5 t/ha vermicompost. 125% RDF + 5 t/ha vermicompost was increased the number of panicles (20.50%), panicle length (23.12%), panicle wt. (13.02%), 1000 grain wt. (12.90%), grain yield (31.15%), straw yield (37.12%), protein content (18.77%), N uptake in grain (36.81%) and straw (42.81%), P uptake in grain (32.62%) and straw (31.56%) and K uptake in grain (35.46%) and straw (25.39%) over control. The lower yield, yield attributes, gross return and nutrient uptake was recorded in control.

Miah *et al*. (2006) stated that an application of poultry manure with soil test basis (STB), IPNS and AEZ based fertilizer gave higher grain yield compared to other organic materials.

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

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

Vanjau and Raju (2002) conducted a field experiment on integrated nutrient management practice in rice crop. Different combinations of chemical fertilizer with poultry manure (PM) 2 t ha^{-1} gave highest grain and straw yield.

While studying the effect of enriched vermicompost on the yield and uptake of nutrient on cowpea at Vellayani (Kerala), Kumari and UshaKumari (2002) observed that enriched vermicompost showed its superiority over other treatments for the uptake of major nutrients like N, P, K, Ca and Mg.

Based on the direct and residual effect of different sources of organic N with fertilizer N and biofertilizers in rice-legume crop sequence at Anamalai Nagar (T.N), Jeyabal and Kuppuswamy (2001) stressed that application of 50% N through vermicompost + 50% via fertilizer N and biofertilizers led to higher grain yield for rice and legume and these yields were higher than those obtained with the application of N through the other combinations

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

A study that was related to the response of scented rice cv Pusa Basmati-1 to different levels of NPK fertilizers (100:50:50, 125:62.5:62.5 and 150:75:75 kg/ha), vermicompost (0 and 5 t/ha), and growth regulator (triacontanol, at 0, 250 and 500 mI/ha) at Siruguppa, (Karnataka), Murali and Setty (2000) revealed that fragrant rice significantly responded to rates of vermicompost. Application of 5 t vermicompost/ha gives rise to potentially higher yield (4889 kg/ha) compared to no vermicompost application.

2.5 Effects of inorganic and organic matters application on soil property

Ilma *et al*. (2012) conducted a field experiment to improve soil physical and chemical properties in organic agriculture. The incorporation of green manure crops, the application of compost and other organic fertilizers and amendments, combined with suitable soil cultivation practices are part of the practices, aimed at achieving this goal. The role of soil microorganisms in achieving optimal nutritional regime in organic agriculture was reviewed. Soil microbial flora control for the enhancement of the domination of the beneficial and effective microorganisms could prove to be a means for the improvement and maintenance of optimal physical and chemical soil properties in organic agriculture.

Results of field experiment at Bhopal (M.P.) to study the effect of different manure viz; vermicompost, phosphocompost, poultry manure and cattle-dung manure vis-a-vis chemical fertilizers on the soil fertility of maize-linseed cropping system, Ramesh *et al.* (2008) discovered that the treatment receiving vermicompost led to record the highest soil OC and available N that at the end of the cropping cycle.

Singh *et al*. (2007) studied the impact of organic farming on yield and quality of Basmati rice and soil properties. It was observed an increase in soil microbial population (Actinomycetes, Bacteria, Fungi, and BGA) due to the application of organic amendments in comparison to absolute control as well as recommended fertilizer application. They again observed a significant increase in soil OC and available P contents due to organic farming practice over control as well as chemical fertilizer application.

From the results of the experiment conducted at Almora (Uttaranchal) to find out the effect of different sources and rates of organic manures (farmyard manure, vermicompost, and poultry manure) on the yield of organically grown up garden pea along with the possible changes in the physicochemical properties of soil, Pandey *et al.* (2006) stressed that application of organic manures, irrespective of sources and rates led to record significant improvement in Physico-chemical properties of soil.

Gaind and Nain (2006) conducted a study to assess the relative contribution of organic fertilizers (paddy straw, microbial inoculants, and vermicompost) and inorganic fertilizers (urea and superphosphate) in improving pH, C, N, humus, microbial biomass, activities of soil under wheat crop. It was observed that vermicompost fertilization resulted into maximum microbial biomass, available P and N contents in soil. They further mentioned that the application of vermicompost was quite effective in minimizing the alkalinity of soil compared to other treatments as indicated by pH change.

Singh *et al.* (2005) highlighted that combined usage of vermicompost and inorganic fertilizers had a better build-up of soil OC and available N, P, and K after crop harvest, in rainfed rice at IARI New Delhi.

Waclawowicz and Parylak (2004) revealed that the application of organic manures caused a non-significant rise in water reserves of the soil and an insignificant decline of soil density, while after using mineral nitrogen fertilization the insignificant increase of capillary capacity of the soil and water reserves of the soil. They further added that both organic manures and nitrogen fertilization improved soil chemical properties by a slight increase of N and P contents in the soil. The application of nitrogen fertilizers exaggerated the decreasing content of potassium in the soil.

Parthasarathi *et al.* (2003) studied the efficacy of vermicompost on the physicochemical and biological properties of the soil and yield and nutrient content of black-gram in comparison to inorganic fertilizers at Sivapuri (T.N). They stressed from the results that the application of vermicompost had a marked influence on the physicochemical and biological properties of soil. It helped to increase the pore space, WHO, OC content, available N, P, K, and microbial population in the soil, besides reduction in particle and bulk masses. On the contrary, the application of inorganic fertilizers had led to a reduction of porosity, compaction of soil, OC content, and microbial population of the soil.

Golabi *et al*. (2007) observed that one of the major problems in agricultural soils is their low organic matter content, which results from rapid decomposition due to the hot and humid environment. Composted organic material is frequently applied on agricultural fields as an amendment to provide nutrients and also to increase the organic matter content and to improve the physical and chemical properties of soils.

Zayed *et al*. (2007, 2008) mentioned that organic fertilizer treatments reduced soil pH levels and more in the second season than in the first. Application of organic fertilizers, especially 5 t ha^{-1} RSC + 110 kg N ha^{-1}, and 7 t FYM + 5 t RSC + Azo., significantly increased soil potassium, zinc and ferrous iron content in both seasons, with the second season results being even higher.

Altieri *et al.* (2003) With the treatment and the other organic fertilizer treatments, it was observed that during the second season, soil organic matter, as well as soil nitrogen and phosphorus content, significantly increased over those values from inorganic fertilizer application. Residual effects of organic fertilizer application were manifested with an increase in soil nutrient availability during the second season. This led to better plant growth, higher dry matter production, improved LAI, and higher plant tissue content of nitrogen and phosphorus.

Hemalatha *et al.* (2000) revealed that green manure significantly increased the soil fertility status, organic carbon, available soil N, P and K at post-harvest soil.

Zaman *et al.* (2000) reported that chemical properties like organic matter content CEC, total N, exchangeable K, available P and S were favorably influenced by the application of organic sources of nitrogen and potassium while the organic sources mostly did not show positive effect. Soil pH decreased slightly compared to the initial status. The literature review discussed above indicates that nitrogen and phosphorus fertilizer greatly influence the yield contributing characters and yield of rice. The properties of soils are also influenced by the inclusion of nitrogen and phosphorus fertilizer.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter includes the information regarding methodology that was used in execution of the experiment. A short description of location of the experimental site, climatic condition, materials and methods used in the experiment, treatments of the experiment, data collection procedure and statistical analysis etc. are presented in this section.

3.1 Experimental period

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh in Boro season during November 2020 to May 2021.

3.2 Description of the experimental site and soil:

3.2.1 Geographical location

The experiment was conducted on the plot no. 21 of experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Madhupur Tract", AEZ-28 (BARC, 2018). The morphological, physical and chemical characteristics of the soil are shown in the Tables 1 and 2. Experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.2 Climate

The climate of the experimental area under the sub-tropical climate that is characterized by high temperature, high humidity and high rainfall with occasional gusty winds during the Kharif season (March-September) and during Rabi season (October-March) scanty rainfall associated with moderately low temperature is observed. The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental area during the cropping season November 2020 to May 2021 have been presented in Appendix II. This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.3 Soil

The soil of the experimental field belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH was 6.7 and has 0.45 percent organic carbon. The land was above flood level and sufficient sunshine was available during the experimental period. Initial soil samples from 0-15 cm depths were collected from the experimental field. The physicochemical properties of the soil in the experimental field are presented in Table 1 and 2.

Table1. Morphological characteristics of the experimental field

Morphology	Characteristics
General Soil Type	Shallow Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

Table 2. Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions:	
% Sand (0.2-0.02 mm)	22.51
% Silt (0.02-0.002 mm)	56.72
% Clay (<0.002 mm)	20.76
Textural class	Silt Loam
pH (1: 2.5 soil- water)	6.7
Organic C (%)	0.45
Organic Matter (%)	1.15
Available P (mg kg^{-1})	19.82
Exchangeable K (meq 100 g^{-1} soil)	0.13
Available S (mg kg^{-1})	14.42

3.3 Experimental Details

3.3.1 Planting Material

BRRI dhan81 is an early maturing highly productive rice variety suitable for Boro season, developed by the Bangladesh Rice Research Institute (BRRI). BRRI dhan81 which has been breed through hybridization crossing between Amol-3 (Iranian rice variety) and BRRI dhan-28. The variety was released in 2017 for cultivation in Boro season. Average grain yield and growth duration of BRRI dhan81 are 6.0-6.5 t ha^{-1} and 140-145 days, respectively.

3.3.2 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD), where the experimental area was divided into 3 blocks representing the replications to reduce the heterogenic effects of soil. There were 4 different potassium and sulphur doses and 3 vermicompost doses. Total plot number was 36 where treatments combinations was 12 applied in three replications. The size of each plot was 5.1 m^2 (3 m x 1.7 m) and plots were separated from each other by 50 cm levee. There was 1 m drain between the blocks that separated the blocks from each other. There was 0.5 m border in all side of land. For better understanding the layout of the experiment has been presented in Figure 1.

Factor A: Potassium and Sulphur

- F_0: Control (no fertilizer)
- F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}
- F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1}
- F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}

Factor B: Vermicompost

- V_0: Control (no vermicompost)
- V_1: 2 t vermicompost ha^{-1}
- V_2: 4 t vermicompost ha^{-1}

Potassium was applied to the plot as MoP and sulphur was applied to plot as gypsum. Except F_0 all potassium and sulphur treatments was associated with recommended dose of nitrogen (Urea), phosphorus (TSP) and zinc (Zinc sulphate). The recommended dose of N, P_2O_5 and Zn for BRRI dhan81 were 104 kg ha^{-1}, 48 kg ha^{-1} and 4 kg ha^{-1} respectively. All the fertilizer was collected from the central experimental farm of Sher-e-Bangla Agricultural University.

3.3 Crop establishment

3.3.1 Seed collection and sprouting

Seeds were collected from Bangladesh Rice Research Institute, Gazipur just 15 days ahead of the sowing of seeds in seed bed. Seeds were soaked in water in a bucket for 24 hours. These were then taken out of water and incubated until emerged. The seeds started sprouting after 48 hours which were suitable for sowing within 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on 6th December 2020 as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 3rd week of November 2020 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design.

3.3.4 Fertilizers application

The potassium, sulphur and vermicompost were applied as per treatments. One third of urea and all the other inorganic fertilizer were applied as basal dose. Rest urea was applied in two equal installments at tillering (20 days after transplanting- DAT) and panicle initiation stage (40 DAT).

3.3.5 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from nine spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.3.6 Transplanting of seedling

Thirty-day-old seedlings of BRRI dhan81 were carefully uprooted from the seedbed and transplanted on 12th January 2021. Three seedlings hill^{-1} were transplanted following 25 cm × 15 cm spacing. After one week of transplanting, all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.3.7 Intercultural operations

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

3.3.7.1 Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

3.3.7.2 Weeding

During plant growth period, two hand weeding were done at 20 and 40 DAT just after urea top dressing

3.3.8 Water management

The experimental plots were irrigated through irrigation channels. Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

3.3.9 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of Diazinone 60 EC @ 1.2 L ha^{-1}. Crop was protected from birds by net during the grain filling period.

3.3.11 General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper was observed during tillering stage. But any bacterial and fungal disease was not observed. The flowering was uniform.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 1st week of May, 2021 when 80-90% of the grains were turned into ripening. The harvested crop was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of rice grain. Fresh weight of rice grain and straw were recorded plot wise from 5.1 m^2 area. The grains were dried, cleaned and weighed for individual plot. The grain and straw weight were adjusted to a moisture content of 14% and 3% respectively and converted to t ha^{-1}.

3.5 Sampling and data collection

- Plant height (cm)
- Total number of tiller $hill^{-1}$
- Number of panicle $hill^{-1}$
- Panicle length (cm)
- Number of spikelets $panicle^{-1}$
- Number of filled spikelets $panicle^{-1}$
- Number of unfilled spikelets $panicle^{-1}$
- 1000 grain weight
- Grain yield and
- Straw yield

Plant height

The height of plant was recorded in centimeter (cm) at maturity during the time of harvesting. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

Total tillers $hill^{-1}$

At maturity, tillers $hill^{-1}$ were counted from 2 x 2 hill sampling units from three places (12 hills $plot^{-1}$) diagonally in each plot (Gomez, 1972). The sample hills were selected excluding border and harvest area. The sample hills were not hills that were replanted or adjacent to a missing hill.

Panicles $hill^{-1}$

At maturity, panicles $hill^{-1}$ was counted from 10 sampling plant from each plot then were averaged. The sample hills were selected excluding border and harvest area. The sample hills were not hills that were replanted or adjacent to a missing hill.

Panicle length

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

Spikelets panicle^{-1}

The total number of spikelets panicle^{-1} was recorded randomly from selected 10 plants of a plot. On the basis of grain in the spikelet and then average numbers of filled spikelets panicle^{-1} was recorded.

Unfilled spikelets panicle^{-1}

The total numbers of unfilled spikelet were collected randomly from selected 10 plants of a plot on the basis of no grain in the spikelet and then average numbers of unfilled spikelets panicle^{-1} was recorded.

Weight of 1000-grain

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in gram and recorded its moisture content. Weight of 1000-grains adjusted at 14% moisture content.

Grain and Straw yield

From the center of each plot, 5 m^2 areas were harvested for determination of grain and straw yields at maturity. After harvest and threshing, grains were sun-dried, and weight and moisture content were measured. Grain yield was adjusted to 14% moisture content, and expressed in t ha^{-1}. Straw was also sun-dried and weighed. Subsamples from the straw were taken and oven-dried at 70^{0}C for 72 h and weighed. Oven-dried weight of straw was recorded. Straw yield was adjusted to 3% moisture content, and expressed in t ha^{-1}. Grain yield was calculated using the following formula (Karmakar, 2016):

$$\text{Grain yield}\,(\text{t ha}^{-1})\ \text{at}\,14\%\,\text{MC} = \frac{(100\text{-}\%\text{M})}{86} \times \frac{\text{Grain wt (kg)}}{\text{Harvested area}\,(\text{m}^2)} \times \frac{10000}{1000}$$

Where,

MC = Moisture content

%M = % MC at weighing of grain

Grain wt. (kg) = Grain weight in kg at the time of weighing grain

Harvested area (m^2) = Sample harvested area in square meter for grain Yield calculation.

3.6 Post harvest soil sampling

After harvest of crop, soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.7 Analyses of soil samples

Soil samples were analyzed for both physical and chemical properties such as texture, pH, organic carbon, total nitrogen, available P and exchangeable K. The soil samples were analyzed following standard methods as follows:

3.7.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al*. (1982).

3.7.2 Organic matter

Organic carbon in soil was determined by wet oxidation method of (Page *et al.*1982). The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

3.7.3 Available P

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5. Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.7.4 Exchangeable K

Exchangeable K in post-harvest soil was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*., 1982).

3.7.5 Available S

Sulphur (S) was determined by turbidimetric method (Tandon, 1995) with the help of spectrophotometer (T60UV). 100 ppm of sulphur standard solution was prepared by dissolving exactly 0.769 g of Epsom salt in 1000 ml volumetric flask containing about 300- 400 ml distilled water. It was shaken thoroughly. The volume was made up to the mark with distilled water. This solution contained 100 ppm S. Then a series of sulphur standard solution was prepared containing 0, 5, 10, 15, 20, 25 and 30 ppm S in seven test tube by pipe ting 0, 1, 2, 3, 4, 5 and 6 ml of 100 ppm of S solution and adding 20, 19, 18, 17, 16, 15 and 14 ml of distilled water from a burette respectively. Acid seed solution was prepared by pouring about 50 ml H_20 into 100 ml volumetric flask, then adding 6.5 ml concentrated HNO_3 (69%), 25 ml of glacial acetic acid, 20 ml of 100 ppm S stock solution and made the volume up to mark with distilled water. After reagent preparation 5 ml of each soil sample was taken in a 25 ml conical flask. Then 1 ml of acid seed solution and 0.30 g barium chloride was added to each standard series and unknown test solutions. After mixing when barium chloride dissolved completely the absorbance reading was taken at 420 nm wavelengths with spectrophotometer.

3.8 Statistical Analysis

The data obtained for different parameters were statistically analyzed and mean values of all the characters were calculated and analysis of variance (ANOVA) was performed by the ‘F’ (variance ratio) test using Statistics 10 computer software. The significance of the difference among the treatment means was compared using the Least Significant Difference (LSD) (Gomez and Gomez, 1984).

Factor A: Potassium + Sulphur

F_0: Control (no fertilizer)

F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}

F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1}

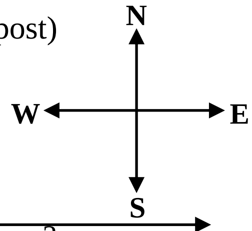
F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}

Factor B: Vermicompost

V_0: Control (no vermicompost)

V_1: 2 t vermicompost ha^{-1}

V_2: 4 t vermicompost ha^{-1}



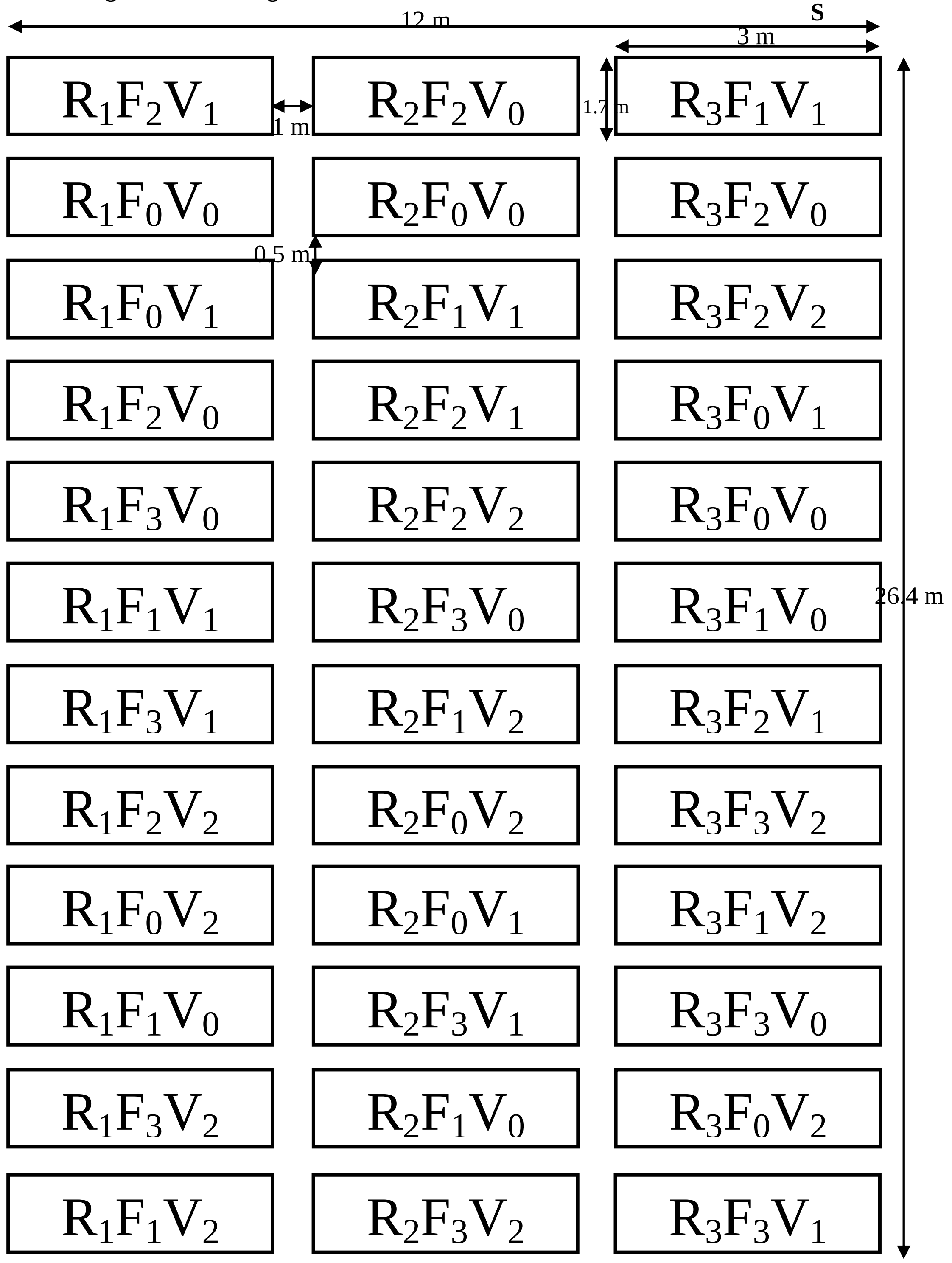


Figure 1: Showing the layout of the experiment

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The research work was accomplished to observe the effect of potassium and sulphur with vermicompost on growth and yield of Boro rice (BRRI dhan81). The results showed differences in terms of different characteristics.

4.1 Plant Height

Plant height of BRRI dhan81 was significantly affected by different potassium and sulphur fertilizer treatments. BRRI dhan81 produced the mean tallest plant (91.8 cm) treated with F_2 which is 100 kg K ha^{-1} and 20 kg S ha^{-1} and the shortest plant (79.4 cm) was found in plants treated with F_0 which is control (Figure 2). Studies confirmed that plant height of rice was increased with application of potassium (Atapattu *et al.*, 2018, Ojha *et al.*, 2021 and Islam and Muttaleb, 2016) and sulphur (Devi *et al.*, 2012 and Singh *et al*., 2012) together.

The vermicompost treatments had significant effects on plant height of rice tested in the experiment. The tallest plant (91.1 cm) was found in the treatment V_2 which is 4 ton vermicompost per hectare while the shortest plant (81.3 cm) was found in treatment V_0 which is control (Figure 3). Results are in line with the findings of Ashadul (2019), Sultana *et al*. (2015) and Bejbaruah *et al.* (2013).

Interaction effects of potassium and sulphur fertilizers and vermicompost treatments on plant height of rice plants were also significant. The tallest plant (97.6 cm) was found in the treatment combination of F_2V_2 which was statistically similar with F_3V_2 (91.8 cm), F_1V_2 (90.6 cm) and F_2V_1 (90.5 cm). On the other hand, the shortest plant (73.1 cm) was found in the treatment F_0V_0 (Figure 4).

It was observed the BRRI dhan81 treated with F_2 (100 kg K ha^{-1} + 20 kg S ha^{-1}) and V_2 (4 t vermicompost $ha^{-}1$) performed the best in case of plant height. Inorganic phosphorus and sulphur containing fertilizer with vermicompost increased the plant height of rice. Similar results were also observed by Fong *et al.* (2022), Kumar *et al*. (2014) and Ji-ming *et al*. (2011).

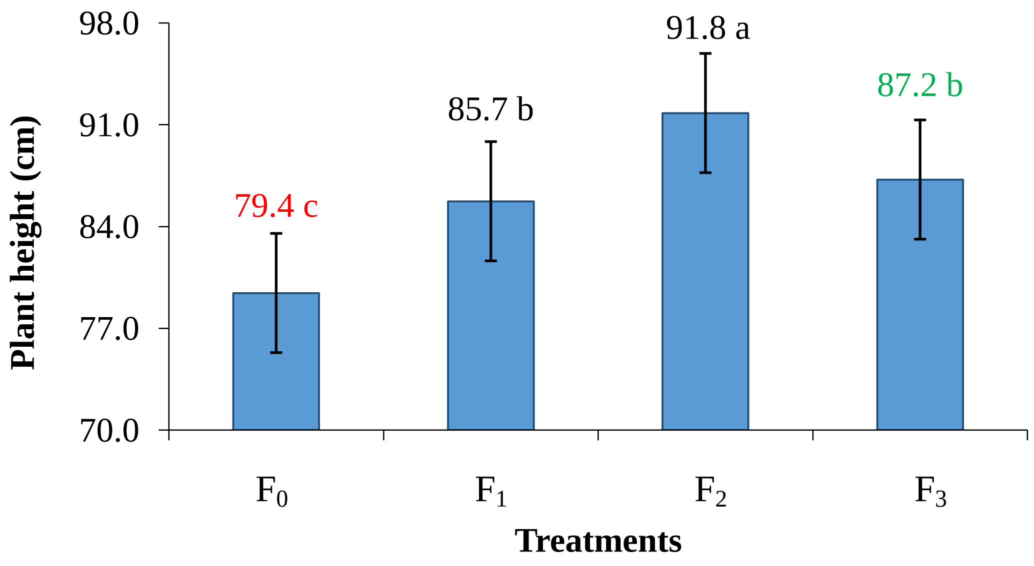


Figure 2. Effect of potassium and sulphur fertilizers treatments on plant height of BRRI dhan81.

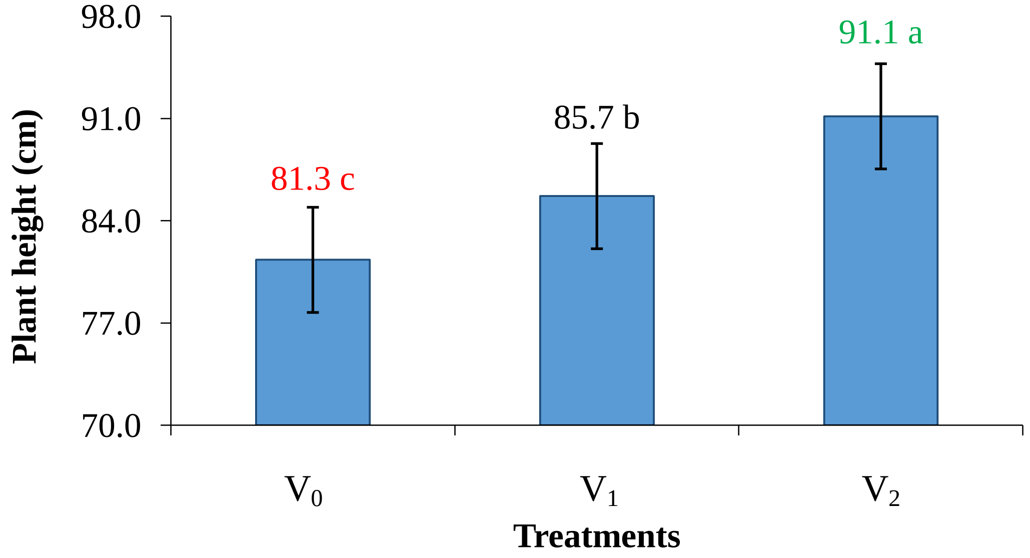


Figure 3. Effect of vermicompost on plant height of BRRI dhan81.

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1}, F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}, V_0: Control, V_1: 2 t vermicompost ha^{-1}, V_2: 4 t vermicompost ha^{-1}

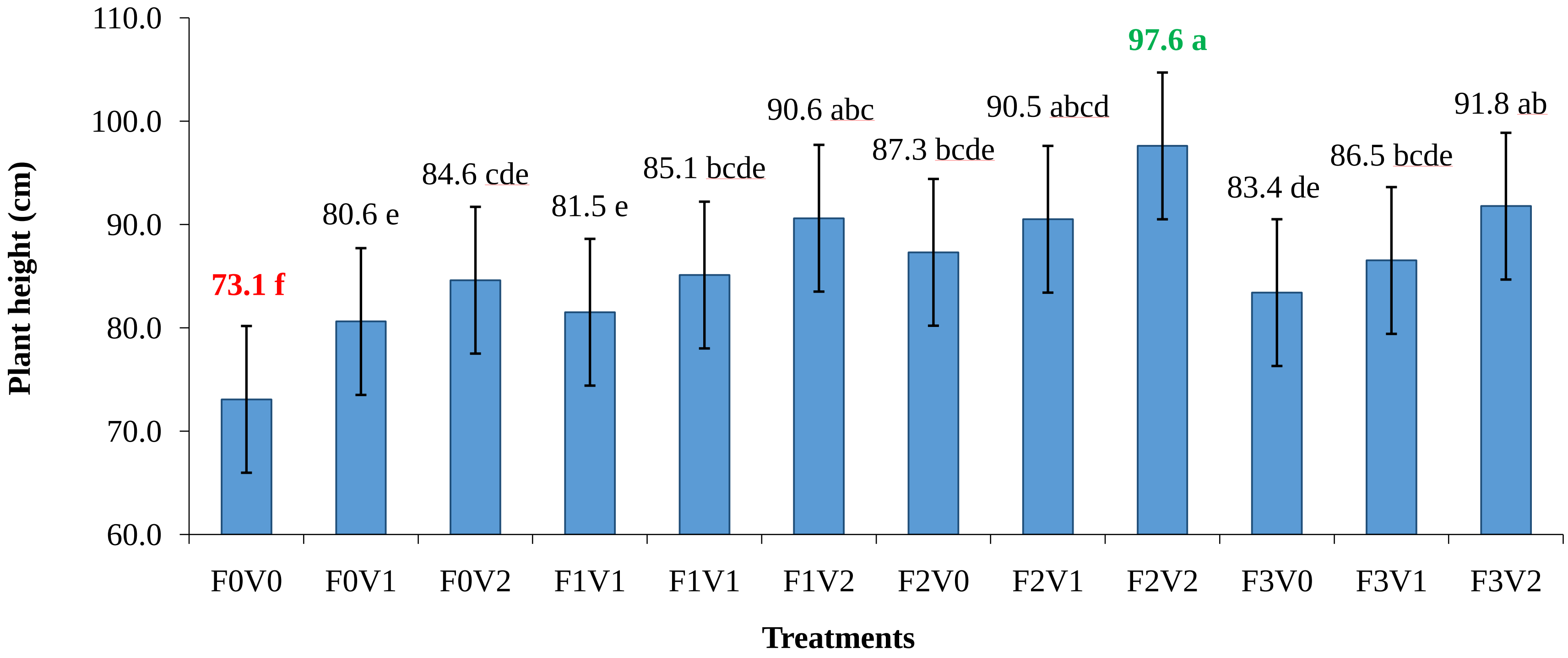


Figure 4: Interaction effect of potassium and sulphur fertilizers and vermicompost treatments on plant height of BRRI dhan81

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1}, F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}, V_0: Control, V_1: 2 t vermicompost ha^{-1}, V_2: 4 t vermicompost ha^{-1}

4.2. Total number of tillers hill^{-1}

Significant variation in producing tillers hill^{-1} by the rice plats were observed at different potassium and sulphur levels. Maximum number of tiller hill^{-1} (16.0) was found in F_2 and the minimum (13.2) was found in F_0 (Figure 5). Similar observation also confirmed that total number of tillers hill^{-1} of rice was increased with application of potassium (Atapattu *et al.*, 2018 and Ojha *et al.*, 2021) and sulphur (Devi *et al.*, 2012 and Singh *et al*., 2012) together.

Total number of tillers hill^{-1} of rice plants significantly differed among the different dose of vermicompost application. The maximum total number of tillers hill^{-1} (15.7) was found with V_2 treatment and the minimum (13.4) was found in V_0 (Figure 6). Results are similar with the findings observed by Ashadul (2019), Sultana *et al*. (2015) and Bejbaruah *et al.* (2013).

There was significant variation among the treatment combinations in case of total number of tillers hill^{-1}. The maximum total number of tillers hill^{-1} (17.9) was found with F_2V_2 treatment and the minimum total number of tillers hill^{-1} (12.3) was found in F_0V_0 (Figure 7). Similar result was also found by Fong *et al.* (2022), Kumar *et al.* (2021), Islam (2020), Kamal, (2020), Mahmud *et al.* (2016).

Higher number of tillers is very important for higher production. Higher number of tillers represents better vegetative growth. If the total number of tillers is higher then there is possibility of better yield. Nutrient supply is prerequisite for better vegetative which may result in higher number of tiller. Inorganic fertilizers contains high amount of nutrients. On the other hand, vermicompost is a slow releasing nutrient rich organic fertilizer which provides a notable amount of humus with other essential nutrients. As a result nutrients are available for a long period of time. It also improves the soil properties which provide a better soil environment for better root growth (Hemalatha *et al.* 2000). The results founded by Ji-ming *et al*. (2011) and Vaiyapuri and Sriramachandrasekharan (2001) are supporting to this results.

4.3 Number of panicles hill^{-1}

The potassium and sulphur fertilizer doses significantly affected the panicle production of BRRI dhan81. The maximum number of panicle hill^{-1} was obtained from treatment F_2 (15.1) while the treatment F_0 (12.3) produced minimum number of panicle hill^{-1} (Figure 5). These findings are in line with other researchers who also found that number of panicles hill^{-1} of rice was increased with application of potassium (Atapattu *et al.,* 2018 and Ojha *et al.,* 2021) and sulphur (Devi *et al.,* 2012 and Singh *et al*., 2012).

There was significant variation found among the vermicompost doses. The maximum number of panicles hill^{-1} (14.8) was obtained from V_2 whereas V_0 produced the minimum number (12.5) of panicles hill^{-1} (Figure 6). Similar result was also observed by Ashadul (2019), Sultana *et al*. (2015) and Bejbaruah *et al.* (2013).

Significant variation was also found among the different types of treatment combinations in case of number of panicles hill^{-1}. Maximum number of panicles hill^{-1} was obtained in the treatment F_2V_2 (16.7) whereas treatment F_0V_0 showed minimum number of panicles hill^{-1} (11.1) (Figure 7).

From this study, it was observed that plants applied with F_2 (100 kg K ha^{-1} + 20 kg S ha^{-1}) and V_2 (4 t vermicompost ha^{-1}) produced the maximum number of panicles hill^{-1}. On the other hand, number of panicle hill^{-1} was the minimum in plants treated with control. Higher the number of effective tillers produces higher no. of panicles resulted higher yield of the rice varieties. Proper supply of potassium and sulphur nutrients helps the tillers to initiate panicle. Panicle production by plant is somewhat genetical, however, better nutrient management can also increase the number of tillers and panicles per unit area that contributed to attain higher yield. At the time of panicle initiation, availability of water and nutrient is crucial. Inorganic and organic fertilizer combination provides nutrients that last longer. That’s why nutrient availability continued for a long time. Vermicompost as an organic manure provides better soil condition. Due to this reason, plants produced higher number of panicle where 100 kg K ha^{-1} + 20 kg S ha^{-1} and 4 t vermicompost ha^{-1} was applied. The findings are in alignment with the results obtained by Ji-ming *et al*. (2011) and Vaiyapuri and Sriramachandrasekharan (2001).

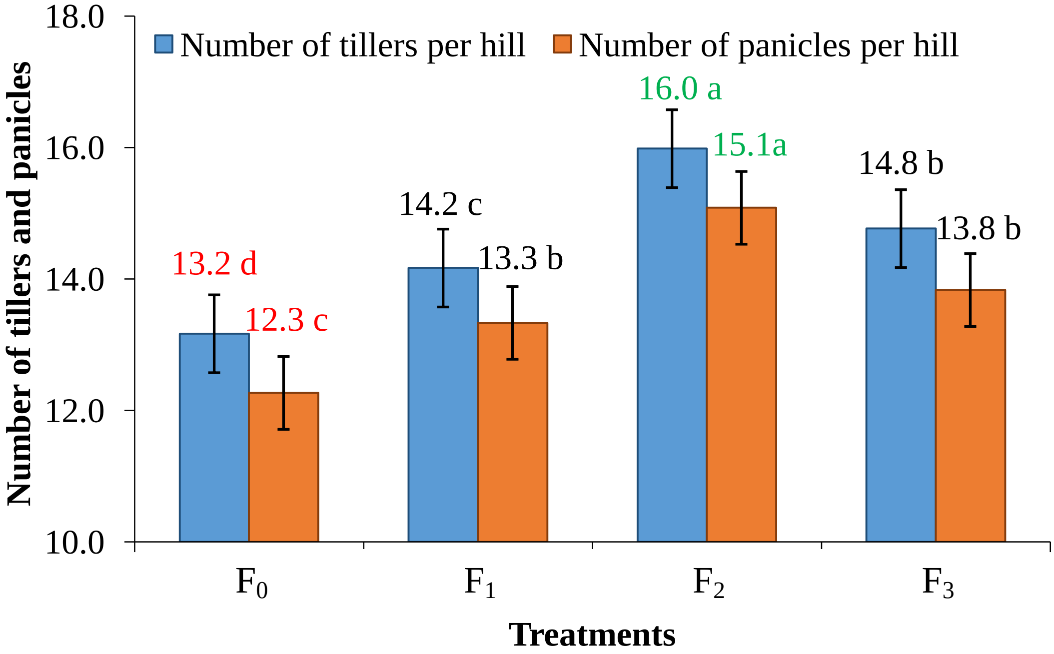


Figure 5. Effect of potassium and sulphur fertilizers treatments on number of tillers and panicles hill^{-1} of BRRI dhan81

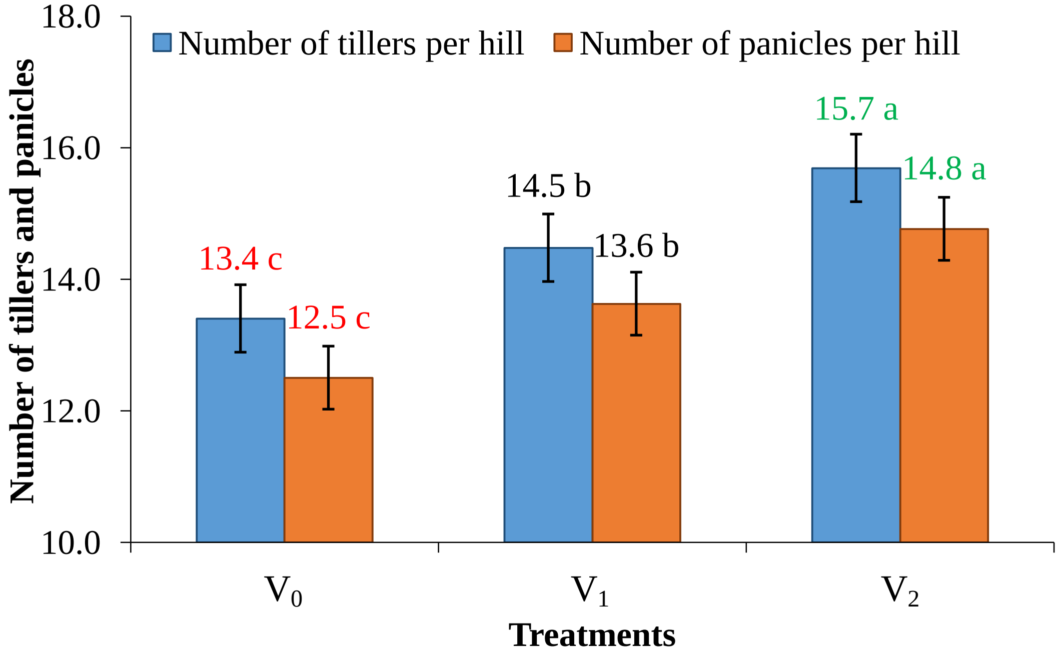


Figure 6. Effect of vermicompost on number of tillers and panicles hill^{-1} of BRRI dhan81.

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

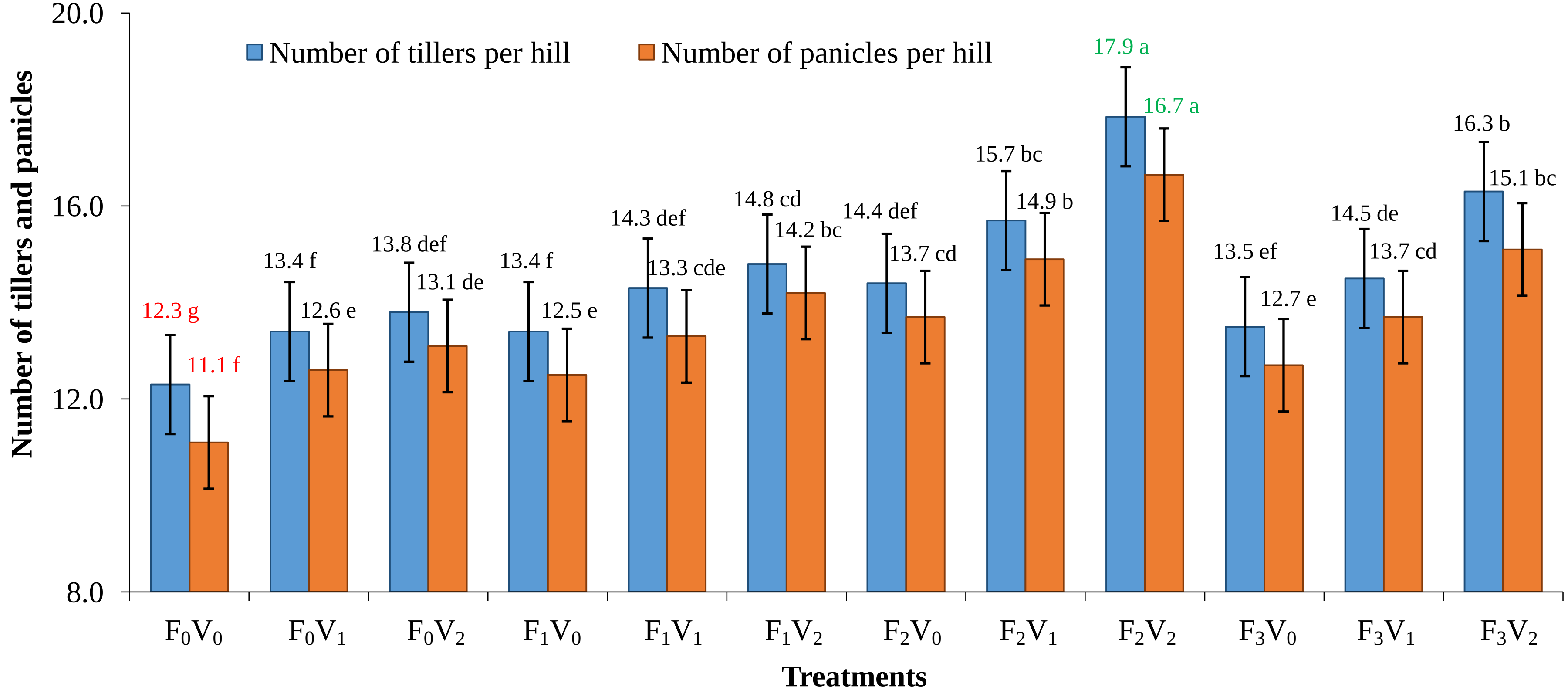


Figure 7. Interaction effect of potassium and sulphur fertilizers and vermicompost treatments on number of tillers and panicles hill^{-1} of BRRI dhan81.

Note: # Vertical bars represent LSD0.05 value.
#F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

4.4 Panicle length

Rice plants showed significant difference among the different doses of potassium and sulphur application in case of panicle length. It was observed that treatment F_2 (21.76 cm) produced the longest panicle which was statistically similar to F_3 (20.80 cm). On the other hand treatment F_0 (18.98 cm) produced the shortest panicle (Table 3). Research findings confirmed that total number of tillers hill^{-1} of rice is was increased with application of potassium (Atapattu *et al.,* 2018 and Ojha *et al.,* 2021) and sulphur (Devi *et al.*, 2012 and Singh *et al.*, 2012) together.

Significant difference was expressed by the rice plants in case of panicle length due to different amount of vermicompost application. From this study it was observed that V_2 (21.36 cm) produced the longest panicle. On the other hand treatment V_0 (19.01 cm) produced the shortest panicle (Table 4). Results observed from the research works of Kheyri (2017), Radzi (2017), Kandan and Subbulakshmi (2015) and Sultana *et al*. (2015) supports the current findings.

It was observed that rice plants expressed no significant difference among the different types treatment combinations in case of panicle length. Treatment F_2V_2 (23.30 cm) produced the longest panicle, which was statistically similar to F_3V_2 (21.40 cm). On the other hand treatment F_0V_0 (18.10 cm) produced the shortest panicle, which was also statistically similar to F_0V_1 (18.58 cm) and F_1V_0 (20.10 cm) (Table 5).

From this research it was observed that applying 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost had the longest panicle. And where no potassium, sulphur and vermicompost were used produced shortest panicle. Kumar *et al*. (2014), Ji-ming *et al*. (2011) and Vaiyapuri and Sriramachandrasekharan (2001) also found this type of result.

4.5 Total number of spikelets panicle^{-1}

Rice plants showed significant difference among the different doses of potassium and sulphur application in case of total number of spikelets panicle^{-1}. It was observed that treatment F_2 (139.04) produced the maximum total number of spikelets panicle^{-1}. On the other hand treatment, F_0 (120.24) produced the minimum total number of spikelets panicle^{-1} (Table 3). Similar observation also confirmed that total number of spikelets panicle^{-1} of rice is was increased with application of potassium with recommended other nutrients (Atapattu *et al.,* 2018 Ojha *et al.,* 2021 and Singh *et al*., 2012).

Total number of spikelets panicle^{-1} of rice plants significantly differed among vermicompost treatments. Maximum number of spikelets panicle^{-1} was found with V_2 (138.23) treatment and the minimum were found in V_0 (122.97) (Table 4). Similar results were observed by Kheyri (2017), Radzi (2017), Kandan and Subbulakshmi, 2015 and Sultana *et al*. (2015) that supports the current findings.

Total number of spikelets panicle^{-1} of rice plants significantly differed among the different types of treatment combinations. Maximum number of spikelets panicle^{-1} was found with F_2V_2 (147.50) treatment which is statistically similar with F_3V_2 (140.18) and the minimum were found in F_0V_0 (109.84) (Table 5).

Study reveals that BRRI dhan81 performed best with applying 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost in case of total number of spikelets panicle^{-1}. Similar findings were observed by Fong *et al.* (2022), Kumar *et al.* (2021), Ji-ming *et al*. (2011) and Vaiyapuri and Sriramachandrasekharan (2001).

4.6 Number of filled spikelets panicle^{-1}

Total number of filled spikelets panicle^{-1} of rice plants significantly differed among the potassium and sulphur treatments. Maximum number of filled spikelets panicle^{-1} was found with F_2 (114.42) treatment and the minimum (87.81) were found in F_0 which is control (Table 3). Potassium and sulphur is very important for better productivity of rice plant. Bhuiyan *et al.* (2011), Islam *et al.* (2006) and Singh *et al.* (2005) observed that application of potassium and sulphur increases the number of filled grain of rice.

Significant difference was observed among the vermicompost treatments in case of number of filled spikelets panicle^{-1} of rice. Maximum number of filled spikelets panicle^{-1} was found with V_2 (113.95) treatment and the minimum was found in V_0 (89.70) (Table 4).

Number of filled spikelets panicle^{-1} of rice plants significantly differed among the treatment combinations of potassium and sulphur treatments with vermicompost. Maximum number of filled spikelets panicle^{-1} was found with F_2V_2 (126.41) treatment and the minimum (72.74) were found in F_0V_0 which is control (Table 5).

Similar results were observed by Kheyri (2017), Radzi (2017) and Sultana *et al*. (2015) that state that vermicompost application increases the number of filled spikelets panicle^{-1}.

The study reveals that application of 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost produced the maximum number of filled spikelets panicle^{-1}. Proper nutrient supply at filling stage is very important for spikelets to be filled. Primary nutrients like nitrogen, potassium, phosphorus, sulphur are supplied as fertilizer and the other nutrients are more or less available in soil. Inorganic fertilizer supplies the entire nutrient on available forms. On the other hand, vermicompost is also rich in these types of nutrients. Vermicompost also contain various types of nutrients. As an organic matter it also improves soil properties which increase the uptake of nutrient water by the plant thus results in higher rate of photosynthesis (Hemalatha *et al.* 2000). Production of food material and their transition to the storage site results in the spikelet to be filled. Kumar *et al.* (2021), Islam (2020), Kamal, (2020), Mahmud *et al.* (2016) and Kumar *et al*. (2014) found the similar result that inorganic potassium and sulphur in combination with vermicompost increases the filled spikelets panicle^{-1}.

4.7 Number of unfilled spikelets panicle^{-1}

Significant variation was found among the potassium and sulphur treatments in case of number of unfilled spikelets panicle^{-1}. Among the four treatments treatment F_2 (24.63) showed lowest and F_0 (32.43) showed highest number of unfilled spikelets panicle^{-1} (Table 3). Deficiency of nutrients causes hamper to the process of grain filling thus increase the number of unfilled spikelets (Bhuiyan *et al.* 2011).

Significant variation was also found among the different doses of vermicompost treatments in case of number of unfilled spikelets panicle^{-1}. Among treatments V_2 (24.28) produced the lowest number of unfilled spikelets and V_0 (33.27) produced the highest number of unfilled spikelets panicle^{-1} (Table 4). Similar results were observed by Kandan and Subbulakshmi (2015) and Sultana *et al*. (2015) that supports the current findings.

Significant variation was also observed among the different combinations of treatments in case of number of unfilled spikelets panicle^{-1}. The treatments combination F_2V_2 (21.09) produced the lowest number of unfilled spikelets panicle^{-1} and combination F_0V_0 (37.10) produced the highest (Table 5).

From this research it was observed that plants applied with 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost produced the lowest number of unfilled spikelet. And the plants supplied with zero potassium, sulphur and vermicompost produced the highest number of unfilled spikelet. Unavailability of nutrient is the main constrain to the spikelets to be filled. Rice plant needs a large amount of nutrient supply apart from those available within the soil itself, this might be the reason why plants lack of nutrient supply failed to fill the spikelet and thus produced higher no of unfilled spikelet. Similar observation was happened with Fong *et al.* (2022), Vaiyapuri and Sriramachandrasekharan (2001) stated that unavailability of proper nutrients and soil organic matter hamper the grain filling of rice.

4.8 Weight of 1000-grain

Significant variation was observed among the different doses of potassium and sulphur treatments in case of weight of 1000-grain. From this study we found that treatment F_2 (19.24 g) produced the maximum weight of 1000-grain which was statistically similar to F_3 (18.57 g). On contrary, treatment F_0 (16.64 g) produced the minimum weight of 1000-grain (Table 3). These results are similar to those obtained by Bhuiyan *et al.* (2011), Islam *et al.* (2006) and Singh *et al.* (2005). On the contrary, Surekha *et al.* (2006) and Kamara *et al.* (2011) reported that 1000-grain weight was not affected significantly by nutrient rates and crop management practices.

Significant variation was found among the vermicompost treatments in case of weight of 1000-grain. From the study it was found that V_2 produced the maximum weight (18.84 g) of 1000-grain. On contrary, V_0 produced the minimum weight (16.96 g) of 1000-grain (Table 4).

Interaction of variety and nutrient managment options had significant effect on weight of 1000-grain of the varities. It was found that the treatment combination F_2V_2 (20.94 g) produced the maximum weight of 1000-grain which was statistically similar to F_3V_2 (19.54 g) and F_2V_1 (19.25 g). On contrary, treatment F_0V_0 (16.11 g) produced the minimum Weight of 1000-grain which was statistically similar to F_0V_1 (16.69 g), F_0V_2 (16.85 g), and F_1V_0 (17.11 g) (Table 5).

From this research it was observed that plants applied with 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost produced the maximum 1000-grain weight. Higher the weight of thousand grain weight represents better grain yield. Grain quality is also determined by the thousand grain weight. The grain weight to be higher, supply of photosynthetic food material produced by plant itself need to be sufficient at the storage point. Phosphorus plays a vital role for photosynthesis. Kumar *et al.* (2021), Mahmud *et al.* (2016), Kumar *et al*. (2014), Ji-ming *et al*. (2011), Vaiyapuri and Sriramachandrasekharan (2001) found the similar result that concludes inorganic nutrients and vermicompost combination increases grain weight of rice.

Table 3: Effects of potassium and sulphur treatments on different attributes of BRRI dhan81

Treatments	Panicle length (cm)	Total number of spikelets panicle^{-1}	Number of filled spikelets panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grain weight (g)
F_0	**18.98 c**	**120.24 c**	**87.81 c**	**32.43 a**	**16.64 c**
F_1	20.33 b	130.70 b	101.55 b	29.15 b	17.72 b
F_2	**21.76 a**	**139.04 a**	**114.42 a**	**24.63 c**	**19.24 a**
F_3	**20.80 ab**	132.48 b	103.77 b	28.71 b	**18.57 ab**
$LSD_{0.05}$	1.27	5.19	5.41	1.45	1.00
C.V.(%)	7.26	6.06	5.43	5.17	5.68

F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}

Table 4: Effects of vermicompost on different attributes of BRRI dhan81

Treatments	Panicle length (cm)	Total number of spikelets panicle^{-1}	Number of filled spikelets panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grain weight (g)
V_0	19.01 b	**122.97 c**	**89.70 c**	**33.27 a**	**16.96 c**
V_1	20.28 b	130.65 b	102.01 b	28.64 b	17.93 b
V_2	21.36 a	**138.23 a**	**113.95 a**	**24.28 c**	**18.84 a**
$LSD_{0.05}$	1.07	4.50	4.69	1.26	0.87
C.V.(%)	7.26	6.06	5.43	5.17	5.68

V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

Table 5: Interaction effects of potassium and sulphur with vermicomposts on different attributes of BRRI dhan81

Treatments	Panicle length (cm)	Total number of spikelets $panicle^{-1}$	Number of filled spikelets $panicle^{-1}$	Number of unfilled spikelets $panicle^{-1}$	1000 grain weight (g)
F_0V_0	**18.10 c**	**109.84 f**	**72.74 e**	**37.10 a**	**16.11 f**
F_0V_1	18.58 bc	121.77 e	87.70 d	34.07 b	**16.69 ef**
F_0V_2	20.26 b	129.10 cde	102.98 c	26.12 cd	**17.11 def**
F_1V_0	20.10 bc	123.71 de	89.19 d	34.52 b	**16.85 ef**
F_1V_1	20.40 b	132.25 bcd	104.42 c	27.83 c	17.92 bcde
F_1V_2	20.50 b	136.12 bc	111.02 bc	25.10 d	**17.88 cde**
F_2V_0	20.80 b	132.53 bcd	105.23 c	27.30 cd	**17.83 cde**
F_2V_1	21.20 b	137.10 bc	111.60 bc	25.50 cd	**19.25 abc**
F_2V_2	**23.30 a**	**147.50 a**	**126.41 a**	**21.09 e**	**20.94 a**
F_3V_0	20.30 b	125.80 de	91.63 d	34.17 b	17.85 de
F_3V_1	20.70 b	131.47 bcd	104.32 c	27.15 cd	18.83 bcd
F_3V_2	**21.40 ab**	**140.18 ab**	115.36 b	24.81 d	**19.54 ab**
$LSD_{0.05}$	2.04	8.98	9.37	2.51	1.73
C.V.$_{(\%)}$	7.26	6.06	5.43	5.17	5.68

F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

4.9 Grain yield (t ha^{-1})

Grain yield per hectare was significantly affected by different doses of potassium and sulphur management treatments. Similar results were confirmed by many researchers who reported that nutrient rates significantly ($p<0.01$) influenced the grain yield might be due to disparity of the potassium (Atapattu *et al.,* 2018 and Ojha *et al.,* 2021) and sulphur (Devi *et al.,* 2012 and Singh *et al*., 2012) nutrient amount applied to the rice plots. Among all the potassium and sulphur treatments, the highest grain yield observed in F_2 (5.95 t ha^{-1}) and the lowest grain yield was found in F_0 (5.02 t ha^{-1}) (Figure 8).

Grain yield significantly varied at different levels of vermicompost supplied. Among the treatments, V_2 produced the highest grain yield (6.05 t ha^{-1}) whereas the lowest grain yield was produced by V_0 (4.99 t ha^{-1}) (Figure 9). These results are in alignment with Ashadul (2019), Kheyri (2017), Radzi (2017), Kandan and Subbulakshmi, 2015, Sultana *et al*. (2015), and Bejbaruah *et al.* (2013) who observed that significant variations existed for grain yield under different vermicompost levels applied to the rice field.

Interaction effect of potassium, sulphur and vermicompost treatments on grain yield also showed significant variations of grain yield of rice. Among the all treatment combinations, F_2V_2 produced the highest grain yield (6.60 t ha^{-1}) while the lowest grain yield (4.40 t ha^{-1}) was in F_0V_0 (Figure 10).

From this research it was observed that plants applied with 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost produced the maximum grain yield. On the other hand, plant with no potassium, sulphur and nor any vermicompost produced the minimum grain yield. Rice grain acts as a storage point for the embryo. Food materials synthesized in leaf but stored in grain. Adequate nutrient supply like potassium and sulphur serves for the synthesis materials prerequisite for photosynthesis and finally assists to increase the photosynthesis rate. Organic manure is very crucial for soil environment and microbes. Vermicompost contains different types of enzymes which influences the proper growth of plant. Nutrient and water uptake is high when organic manure is in adequate in soil. Fong *et al.* (2022), Kumar *et al.* (2021), Islam (2020), Kamal, (2020), Mahmud *et al.* (2016), Kumar *et al*. (2014) and Ji-ming *et al*. (2011) found that application of inorganic nutrient with organic manure increases grain yield of rice.

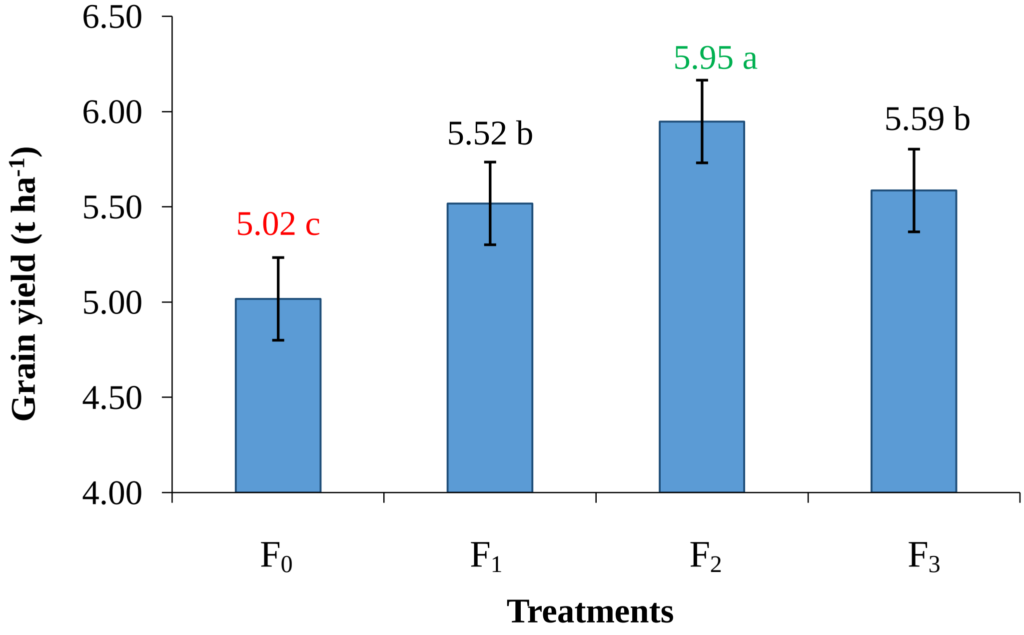


Figure 8. Effect of potassium and sulphur on grain yield of BRRI dhan81.

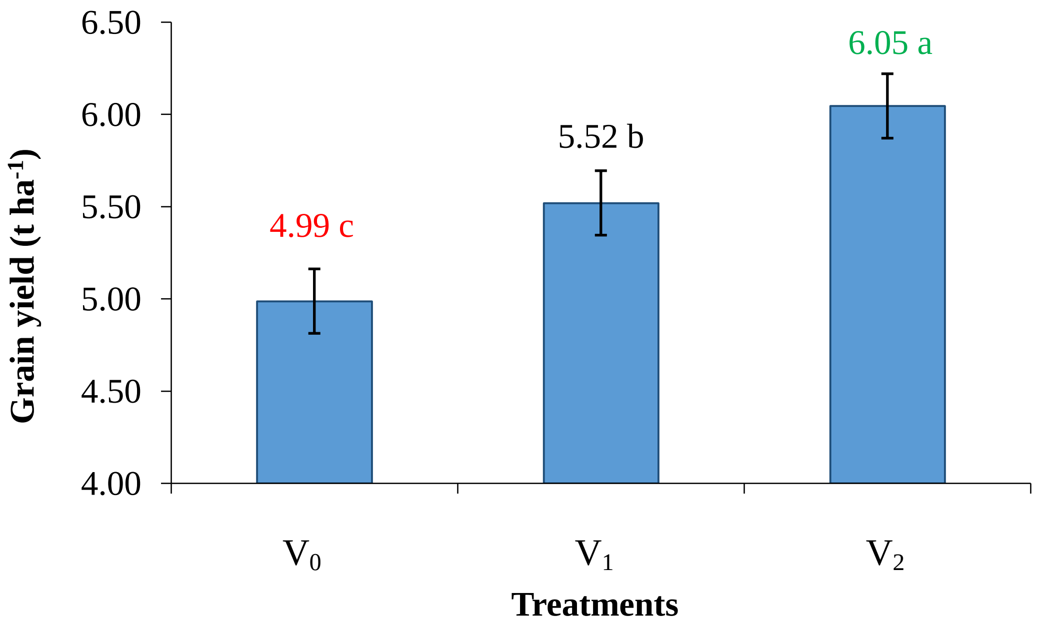


Figure 9. Effect of vermicompost on grain yield of BRRI dhan81.

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

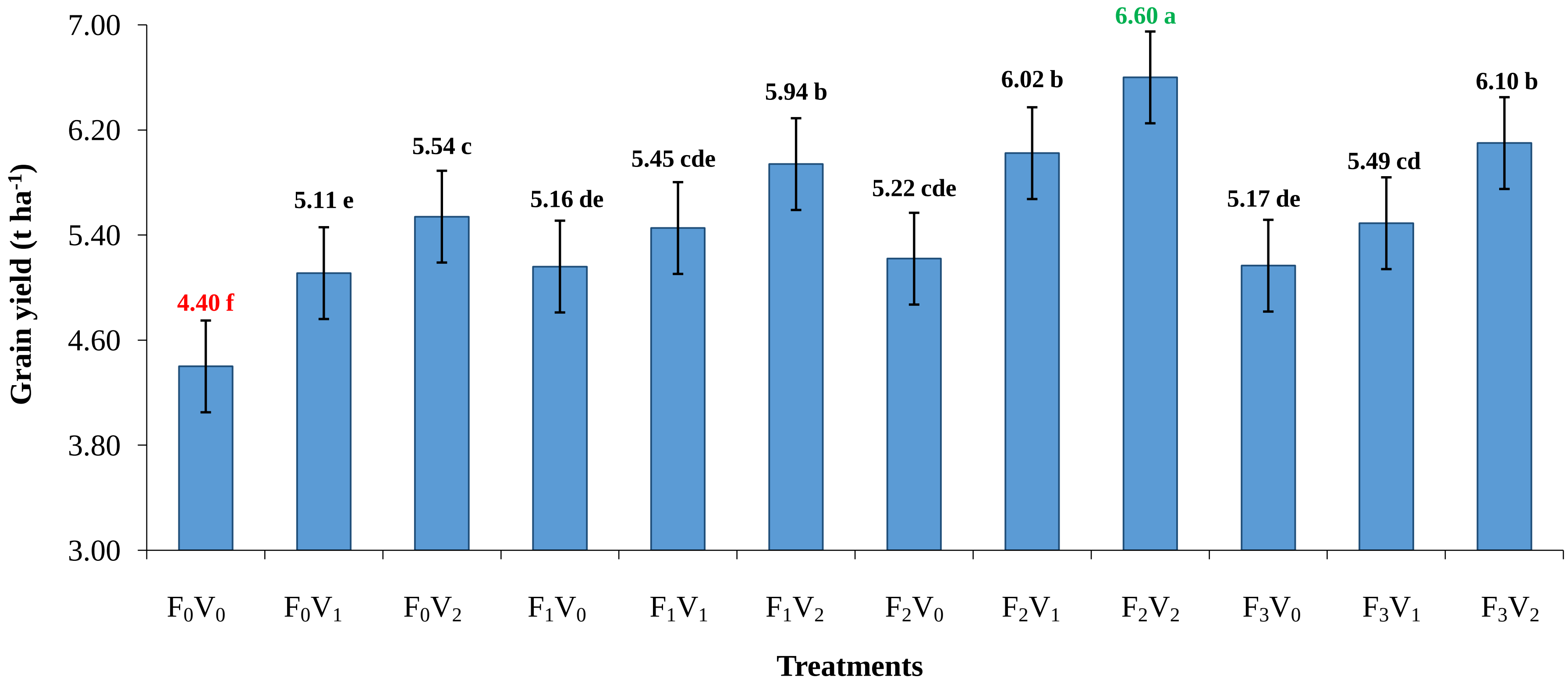


Figure 10. Interaction effect of potassium and sulphur with vermicompost treatments on grain yield.

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

4.10 Straw yield (t ha^{-1})

Straw yield per hectare was significantly affected by different types of potassium and sulphur management treatments. Among the potassium and sulphur treatments, the highest straw yield observed in F_2 (7.80 t ha^{-1}) and the lowest straw yield was in F_0 (6.31 t ha^{-1}) (Figure 11). Similar results were found that confirmed that nutrient rates significantly ($p<0.01$) influenced the grain yield might be due to the disparity of potassium (Atapattu *et al.*, 2018 and Ojha *et al.*, 2021) and sulphur (Devi *et al.*, 2012 and Singh *et al.*, 2012) nutrient amount applied to the rice plots.

Straw yield significantly differed at different levels of vermicompost supplied. Among the treatments, V_2 produced the highest straw yield (7.76 t ha^{-1}) whereas the lowest straw yield was produced by V_0 (6.56 t ha^{-1}) (Figure 12). Ashadul (2019), Kheyri (2017), Radzi (2017), Kandan and Subbulakshmi, 2015 and Bejbaruah *et al.* (2013) also found the similar results.

Interaction effect of potassium and sulphur with vermicompost was significant on straw yield of rice. Among the all treatment combinations, F_2V_2 produced the highest straw yield (8.74 t ha^{-1}) while the lowest straw yield (5.51 t ha^{-1}) was in F_0V_0 (Figure 13).

From this research it was observed that plants applied with 100 kg K ha^{-1} and 20 kg S ha^{-1} with 4 t ha^{-1} vermicompost produced the maximum straw yield. On the other hand, plant with no potassium, sulphur and nor any vermicompost produced the minimum straw yield. Supply of inorganic nutrient with organic matter helps to higher productivity (Vaiyapuri and Sriramachandrasekharan, 2001). Fong *et al.* (2022), Kumar *et al.* (2021), Kamal (2020), Mahmud *et al.* (2016), and Ji-ming *et al*. (2011) and many other researchers also found the similar results.

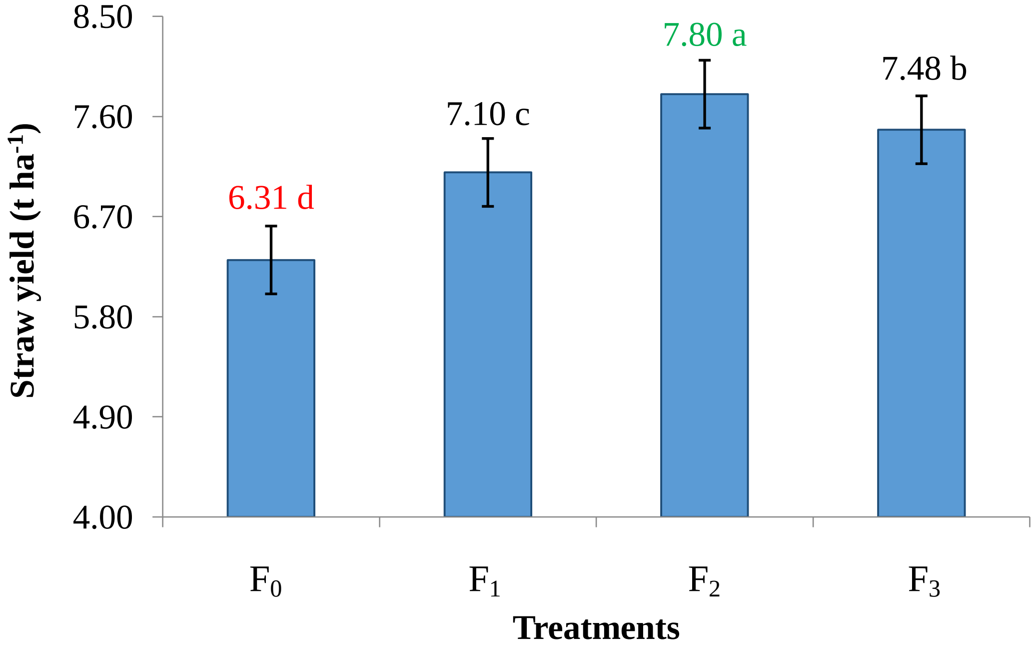


Figure 11. Effect of potassium and sulphur on straw yield of BRRI dhan81.

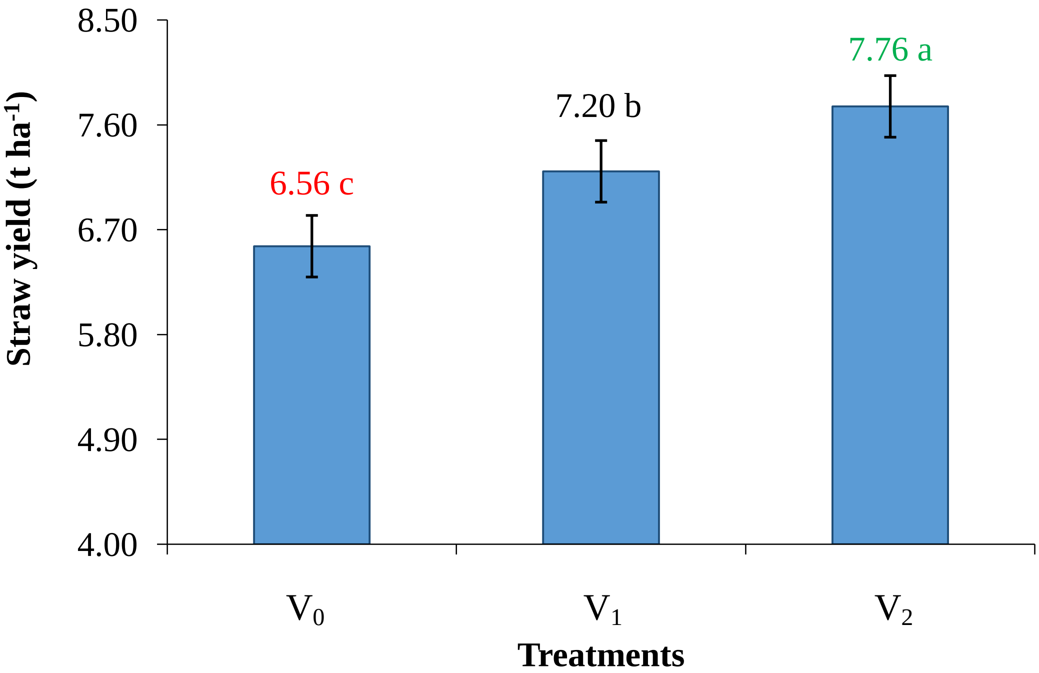


Figure 12. Effect of vermicompost on straw yield of BRRI dhan81.

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

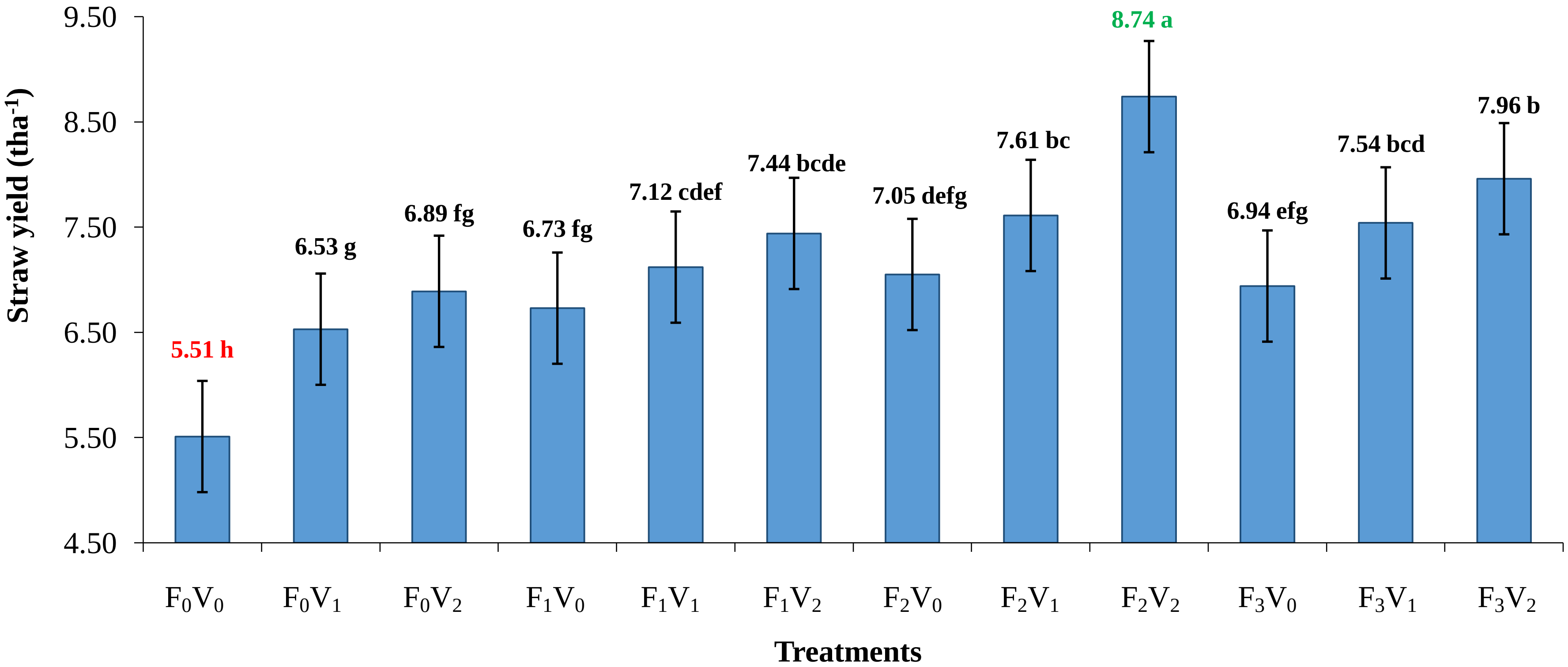


Figure 13. Interaction effect of potassium and sulphur with vermicompost on straw yield of BRRI dhan81.

Note: # Vertical bars represent $LSD_{0.05}$ value.
F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control; V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

4.11 Properties post-harvest of soil

4.11.1 pH of post-harvest Soils

No significant variation was recorded in post-harvest soil pH due to application of different amount of potassium, sulphur and vermicompost also for their combined use (Table 6). Although there was no significant difference among the treatments, the highest pH of post-harvest soil (6.3) was found from F_3. It was observed that pH increased with the increased of amount potassium applied to the soil. There were no significant variation recorded also in post-harvest soil pH due to application of vermicompost application (Table 7). Treatments combination also showed no significant variation in case of pH of postharvest soil. Highest pH was found in case of F_3V_0 which was 6.4 (Table 8).

4.11.2 Organic matter content of post-harvest soil

It was found that organic matter status of post-harvest soil statistically differed due to application of potassium and sulphur. The maximum organic matter content of post-harvest soil (1.38%) was found from F_2 which was statistically identical with F_3 (1.36%). The lowest organic matter of post-harvest soil (1.25%) was recorded from F_0 (Table 6).

Table 6 is showing the effects of varmicompost on organic matter status of post-harvest soils. It was found that differences in organic matter status of post-harvest soil were statistically significant. The maximum organic matter of post-harvest soil (1.37%) was found from V_2. The lowest organic matter of post-harvest soil (1.28%) was recorded from V_0 (Table 7).

It was also found that organic matter status of post-harvest soil statistically differed due to different combinations of variety and fertilizers. The maximum organic matter of post-harvest soil (1.43%) was found from F_2V_2 which was statistically similar with F_3V_2 (1.39) and F_2V_1 (1.38). The lowest organic matter of post-harvest soil (1.20%) was recorded from F_0V_0 which was statistically identical with F_0V_1 (1.24%) and statistically similar with F_1V_0 (1.25%) (Table 8). Combination of potassium, sulphur and vermicompost improved soil organic matter content was also observed by Golabi *et al*. (2007), Altieri *et al*. (2003).

4.12.3 Available P

Available P in post-harvest soil showed statistically significant differences due to the effect of different potassium and sulphur fertilizer treatments (Table 6). The highest available P (35.87 ppm) was observed from F_2 treatment which was statistically identical with F_3 (35.05 ppm) whereas the lowest available P (25.36 ppm) was found from F_0 treatment (Table 6) also reported the similar type of result.

Available P in post-harvest soil showed statistically significant differences due to the application vermicompost. The highest available P (35.41 ppm) was observed from V_2 treatment, whereas the lowest available P (28.09 ppm) was found from V_0 treatment (Table 7).

It was also found that available P status of post-harvest soil statistically differed due to different combinations of treatments. The maximum available P content of post-harvest soil (39.24 ppm) was found from F_2V_2, which was statistically similar with F_3V_2 (37.70 ppm), F_2V_1 (35.90 ppm) and F_3V_1 (35.34 ppm). The lowest available P content of post-harvest soil (18.41 ppm) was recorded from F_0V_0 (Table 8).

4.12.4 Exchangeable K

Statistically significant difference was recorded in terms of exchangeable K in post-harvest soil due to different fertilizer treatments (Table 6). The highest exchangeable K (0.155 meq/100 g soil) was observed from F_3 treatment, which was statistically similar to with F_2 (0.149 meq/100 g soil) and the lowest exchangeable K (0.123 meq/100 g soil) was recorded from F_0 treatment (Table 6).

Exchangeable K in post-harvest soil showed statistically significant differences due to vermicompost treatments. The highest exchangeable K (0.154 meq/100 g soil) was observed from V_2 treatment and the lowest exchangeable K (0.126 meq/100 g soil) was recorded from V_0 treatment (Table 7).

It was also found that Exchangeable K status of post-harvest soil statistically differed due to different treatment combinations. The maximum exchangeable K content of post-harvest soil (0.172 meq/100 g soil) was found from F_3V_2 which was statistically similar to F_2V_2 (0.163 meq/100 g soil), F_3V_1 (0.161 meq/100 g soil) and F_2V_1 (0.154

meq/100 g soil). The lowest exchangeable K content of post-harvest soil (0.110 meq/100 g soil) was recorded from F_0V_0 (Table 8). It was supported by the studies by Golabi *et al*. (2007), Altieri *et al*. (2003).

4.12.5 Available S

Statistically significant difference was recorded in terms of available S in post-harvest soil due to different fertilizer treatments. The highest available S (16.30 ppm) was observed from F_3 treatment, which was statistically identical with F_2 (15.87 ppm) and the lowest available S (13.20 ppm) was recorded from F_0 treatment (Table 6). It was observed that sulphur availability increased with the increase in sulphur applied to the soil.

Available S in post-harvest soil presented statistically significant differences due to vermicompost application. The highest available S (16.12 ppm) was observed from V_2 treatment and the lowest available S (13.84 ppm) was recorded from V_0 treatment (Table 7).

It was observed that significant difference was found in case of available S status of post-harvest soil due to different treatment combinations. The maximum available S content of post-harvest soil (17.45 ppm) was found from F_3V_2 which was statistically similar to F_2V_2 (16.96 ppm), F_3V_1 (16.26 ppm), F_2V_1 (15.88 ppm) and F_1V_2 (15.57 ppm). On the other hand the minimum available S content was found in F_0V_0 (11.97 ppm) which was statistically similar to F_0V_1 (13.17 ppm) and F_1V_0 (13.47 ppm) (Table 8).

Table 6: Effects of potassium and sulphur treatments on nutrient content of post harvest soil

Treatments	pH	Organic matter content (%)	Available p content (ppm)	Exchangeable K content (meq/100g)	Available S (ppm)
F_0	6.13	1.25 c	25.36 c	0.123 c	13.20 c
F_1	6.03	1.32 b	32.26 b	0.140 b	14.67 b
F_2	6.13	1.38 a	35.87 a	0.149 ab	15.87 a
F_3	6.30	1.36 a	35.05 a	0.155 a	16.30 a
$LSD_{0.05}$	ns	0.03	2.44	0.011	1.11
C.V.$_{(\%)}$	7.64	4.27	7.78	7.54	7.59

F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}

Table 7: Effects of vermicompost on nutrient content of post harvest soil

Treatments	pH	Organic matter content (%)	Available p content (ppm)	Exchangeable K content (meq/100g)	Available S (ppm)
V_0	6.20	1.28 c	28.09 c	0.126 c	13.84 c
V_1	6.15	1.33 b	32.91 b	0.145 b	15.07 b
V_2	6.08	1.37 a	35.41 a	0.154 a	16.12 a
$LSD_{0.05}$	ns	0.03	2.12	0.010	0.97
C.V.$_{(\%)}$	7.64	4.27	7.78	7.54	7.59

V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

Table 8: Interaction effects of potassium and sulphur with vermicomposts on nutrient content of post harvest soil

Treatments	pH	Organic matter content (%)	Available p content (ppm)	Exchangeable K content (meq/100g)	Available S (ppm)
F_0V_0	6.0	1.20 g	18.41 g	0.110 e	11.97 f
F_0V_1	6.2	1.24 g	27.36 f	0.128 d	13.17 ef
F_0V_2	6.1	1.30 ef	30.32 def	0.131 d	14.46 cde
F_1V_0	6.1	1.25 fg	29.37 ef	0.131 d	13.47 def
F_1V_1	5.9	1.34 bcde	33.03 cde	0.138 cd	14.98 cde
F_1V_2	6.0	1.36 bcd	34.38 bcd	0.152 d	15.57 abc
F_2V_0	6.2	1.33 cde	32.46 cde	0.133 d	14.75 cde
F_2V_1	6.1	1.38 abc	35.90 abc	0.154 abc	15.88 abc
F_2V_2	6.0	1.43 a	39.24 a	0.163 ab	16.96 ab
F_3V_0	6.4	1.32 de	32.12 cde	0.152 bc	15.17 bcd
F_3V_1	6.3	1.37 bcd	35.34 abc	0.161 ab	16.26 abc
F_3V_2	6.1	1.39 ab	37.70 ab	0.172 a	17.45 a
$LSD_{0.05}$	ns	0.05	4.23	0.018	1.93
C.V.$_{(\%)}$	7.64	4.27	7.78	7.54	7.59

F_0: Control, F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1}; V_0: Control, V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}

CHAPTER V

SUMMERY AND CONCLUSION

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SUMMERY

Rice is needed a sensible management of fertilization for better production. Mentionable amount of nutrient is lost from the soil in various ways like runoff, fixation, leaching, and volatilization. Reduction of organic matter is also a major constrain to the productivity of soil in Bangladesh. So it is necessary to adopt some new fertilizer management to overcome these problems.

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Boro season of November 2020 to May 2021, with a view to observe the showed differences in terms of different characters at Boro season due to different types of fertilizer managements.

There were altogether two factors. Factor A: four potassium and sulphur fertilizer treatments viz: F_0: Control (no fertilizer), F_1: 70 kg K ha^{-1} + 10 kg S ha^{-1}, F_2: 100 kg K ha^{-1} + 20 kg S ha^{-1} and F_3: 130 kg K ha^{-1} + 30 kg S ha^{-1} and Factor B: three vermicompost treatments viz: V_0: Control (no vermicompost), V_1: 2 t vermicompost ha^{-1} and V_2: 4 t vermicompost ha^{-1}. In total twelve treatment combinations were there consisting of potassium, sulphur and vermicompost.

BRRI dhan81 produced the mean tallest plant (91.8 cm) treated with F_2 which is 100 kg K ha^{-1} and 20 kg S ha^{-1} and the shortest plant (79.4 cm) was found in plants treated with control. For the vermicompost tallest plant (91.1 cm) was found in the treatment V_2 while the shortest plant (81.3 cm) was found in treatment V_0. Among the treatment combinations the tallest plant (97.6 cm) was found in the treatment combination of F_2V_2 while the shortest plant (73.1 cm) was found in the treatment F_0V_0.

Among the potassium and sulphur treatments the maximum number of tillers $hill^{-1}$ (16.0) and panicles $hill^{-1}$ (15.1) was found in F_2 and the minimum number of tillers $hill^{-1}$ (13.2) and panicles $hill^{-1}$ (12.3) was found in F_0. Among the vermicompost treatments the maximum number of tillers $hill^{-1}$ (15.7) and panicles $hill^{-1}$ (14.8) was found in V_2 and the minimum number of tillers $hill^{-1}$ (13.4) and panicles $hill^{-1}$ (12.5) was found in F_0. Treatment combination F_2V_2 produced the maximum number of tillers hill^{-1} (17.9) and panicles hill^{-1} (16.7) where as treatment F_0V_0 showed minimum number of tillers hill^{-1} (12.3) and panicles hill^{-1} (11.1).

In case of panicle length treatment F_2 (21.76 cm) produced the longest panicle and treatment F_0 (18.98 cm) produced the shortest panicle as effect of potassium and sulphur. Among the vermicompost it was observed that V_2 (21.36 cm) produced the longest panicle and treatment V_0 (19.01 cm) produced the shortest panicle. Finally treatment combination F_2V_2 (23.30 cm) produced the longest panicle which was statistically similar to F_3V_2 (21.40 cm) while treatment F_0V_0 (18.10 cm) produced the shortest panicle which was also statistically similar to F_0V_1 (18.58 cm) and F_1V_0 (20.10 cm).

Among the potassium and sulphur treatments F_2 produced highest number of total, filled and unfilled spikelets panicle^{-1} (139.04, 114.42 and 24.63 respectively). On the other hand F_0 produced the lowest number of total, filled and unfilled spikelets panicle^{-1} (120.24, 87.81 and 32.43 respectively). For vermicompost V_2 produced highest number of total, filled and unfilled spikelets panicle^{-1} (138.23, 113.95 and 24.28 respectively) while F_0 produced the lowest number of total, filled and unfilled spikelets panicle^{-1} (122.97, 89.70 and 33.27 respectively). Among the combinations F_2V_2 produced maximum total number of grains panicle^{-1}, filled grains and unfilled grains (147.50, 126.41 and 21.09 respectively) and F_0V_0 produced minimum (109.84, 72.74 and 37.10 respectively).

Among the potassium and sulphur treatments F_2 (19.24 g) produced the maximum weight of 1000-grain and treatment F_0 (16.64 g) produced the minimum. For vermicompost V_2 (18.84 g) produced maximum weight of 1000-grain while V_0 (16.96 g) produced the minimum. Among the combinations F_2V_2 (20.94 g) produced the maximum weight of 1000-grain and treatment F_0V_0 (16.11 g) produced the minimum weight of 1000-grain.

Among the all potassium and sulphur treatments, the highest grain yield observed in F_2 (5.95 t ha^{-1}) and the lowest grain yield was found in F_0 (5.02 t ha^{-1}). Among the vermicompost treatments, V_2 produced the highest grain yield (6.05 t ha^{-1}) whereas the lowest grain yield was produced by V_0 (4.99 t ha^{-1}). For treatment combinations, F_2V_2 produced the highest grain yield (6.60 t ha^{-1}) while the lowest grain yield (4.40 t ha^{-1}) was in F_0V_0.

In case of straw yield among the all fertilizer treatments, the highest straw yield observed in F_2 (7.80 t ha^{-1}) and the lowest straw yield was in F_0 (6.31 t ha^{-1}). For vermicompost V_2 produced the highest straw yield (7.76 t ha^{-1}) whereas the lowest straw yield was produced by V_0 (6.56 t ha^{-1}) (Figure 12). On the other hand combinations, F_2V_2 produced the highest straw yield (8.74 t ha^{-1}) while the lowest straw yield (5.51 t ha^{-1}) was in F_0V_0.

No significant variation was recorded in post-harvest soil pH due to application of different treatments. Organic carbon content and available P of of postharvest soil was highest for plot applied with 100 kg ha^{-1} potassium and 20 kg ha^{-1} sulphur with 4 t ha^{-1} vermicompost but exchangeable K and available S of post harvest soil was highest for 130 kg ha^{-1} potassium and 30 kg ha^{-1} sulphur with 4 t ha^{-1} vermicompost.

CONCLUSION

Regarding as the above results, it could be concluded that among the potassium and sulphur treatments, F_2 (100 kg ha^{-1} potassium and 20 kg ha^{-1} sulphur) and among the vermicompost treatments V_2 (4 t ha^{-1} vermicompost) were the best in respect of yield and yield components. Moreover, F_2V_2 (100 kg ha^{-1} potassium and 20 kg ha^{-1} sulphur in combination with 4 t ha^{-1} vermicompost) performed the best in case of most of the vegetative and yield characteristics like plant height, panicle length, total number of tillers and panicles $hill^{-1}$, Number of filled and Unfilled spikeletes, 1000 grain weight, straw and grain yield. Therefore 100 kg ha^{-1} potassium and 20 kg ha^{-1} sulphur in combination with 4 t ha^{-1} vermicompost would be recommended to attain best performance and sustainable cultivation of Boro rice (BRRI dhan81).

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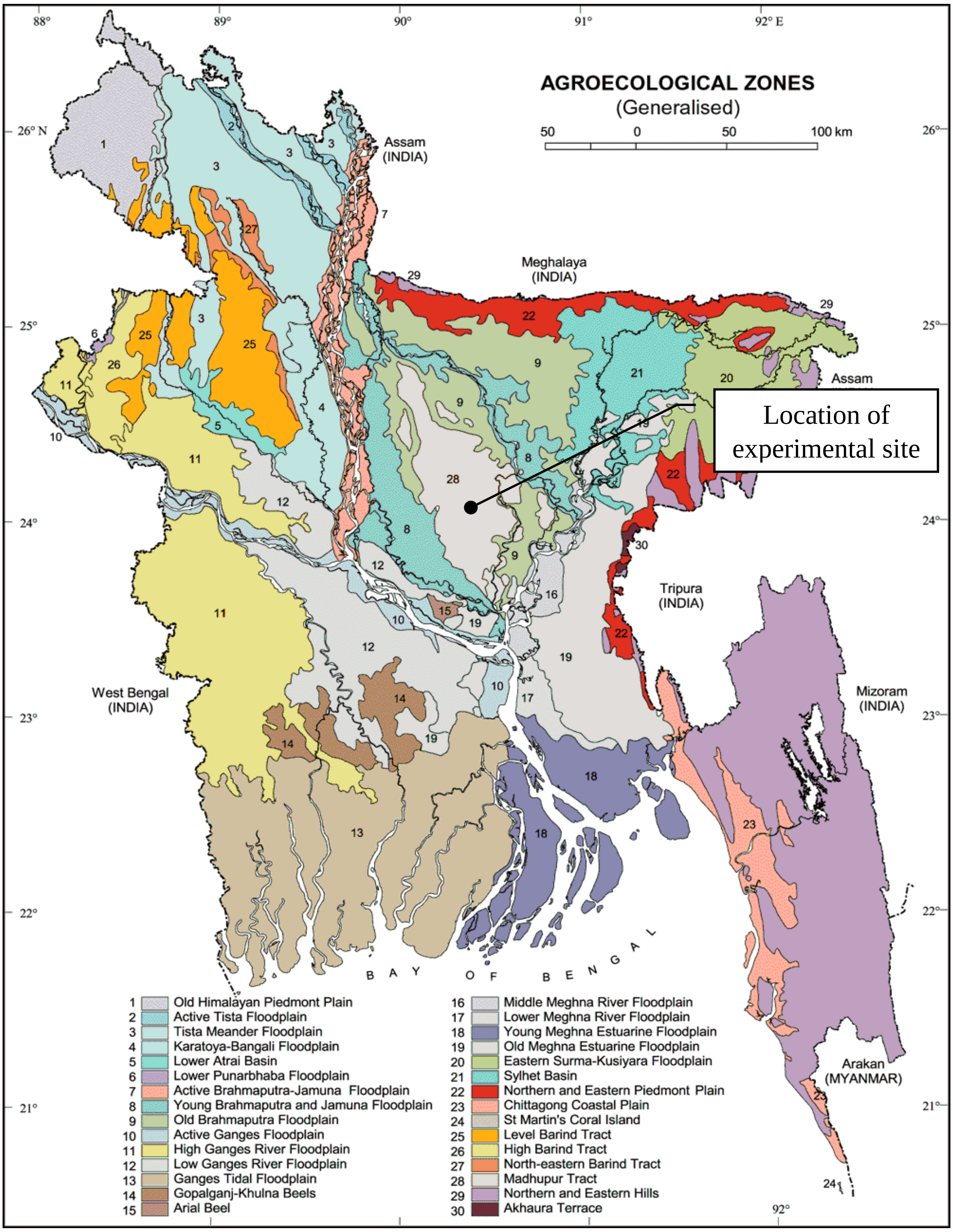
APPENDICES

APPENDICES

Appendix I: Map showing the location of the site of the experiment.



Appendix II: Morphological characteristics of the experimental field.

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

Appendix III: Physical and chemical properties of the soil

Characteristics	Value
Particle size analysis	
% Sand	22.51
% Silt	56.72
% Clay	20.76
Textural class	Silt loam
Consistency	Granular and friable when dry
pH	6.7
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.53
Organic carbon (%)	0.45
Organic matter (%)	1.15
Available P (ppm)	19.82
Exchangeable K (meq/100g soil)	0.13

Appendix IV: ANOVA table for different attributes

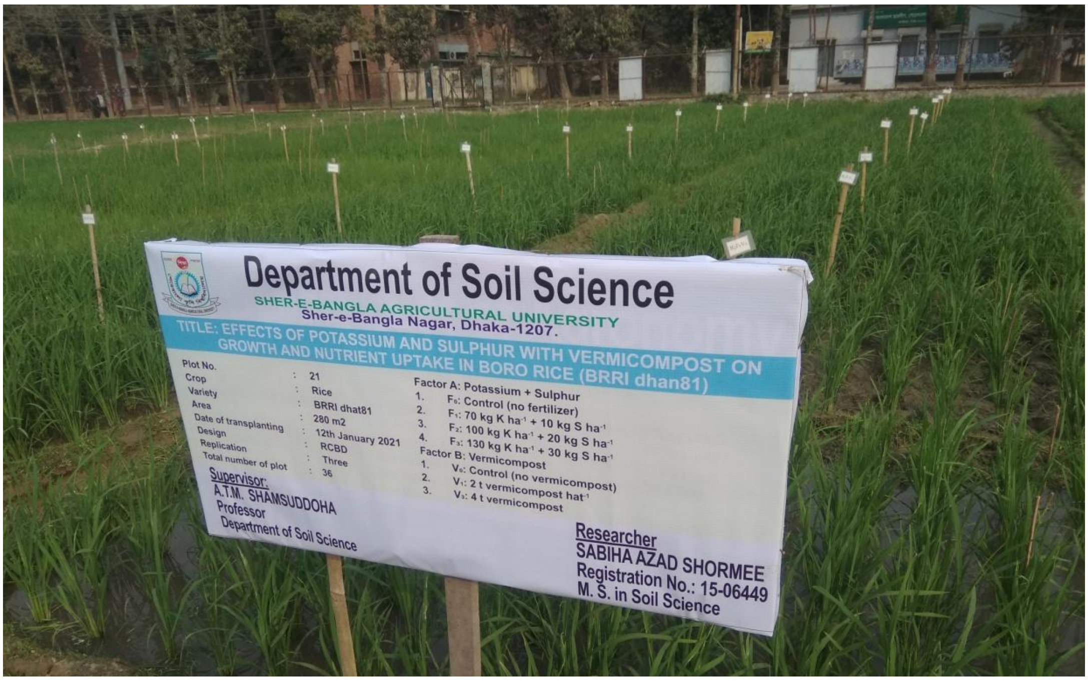
Source of variation	Degrees of freedom	Mean Squares						
		Plant height	Number of tiller hill^{-1}	Number of panicles hill^{-1}	Panicle length	Number of spikelets panicle^{-1}	Number of filled spikelets panicle^{-1}	Number of unfilled spikelets panicle^{-1}
R	2	19.668*	0.2902	0.3952	11.0126	192.258	76.32	1.771
F	3	235.416**	12.4756*	12.3006*	6.7795*	546.832**	1076.66**	92.033**
V	2	290.809**	15.7169*	15.3569*	5.5501*	698.231**	1763.97**	242.628**
F*V	6	4.036*	0.9169*	0.3419*	0.8295*	13.438*	25.21*	8.685*
Error	22	17.593*	0.3671	0.3207	2.248	28.135*	30.64*	2.196

* Significant at 0.05 level
** Significant at 0.01 level

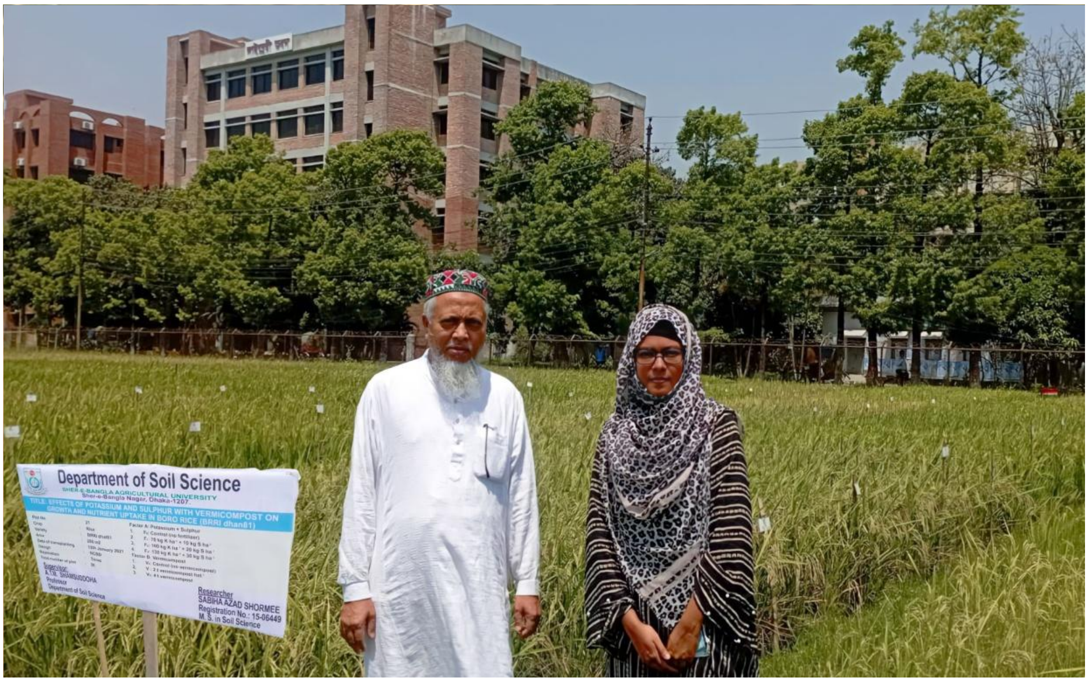
Appendix V: ANOVA table for different attributes

Source of variation	Degrees of freedom	Mean Squares								
		1000-Grain weight	Grain Yield	Straw Yield	pH	Organic matter content	Total N content	Available p content	Exchangeable K content	Available S content
R	2	0.943	0.05412	0.11581	1.21333	0.00216	3.58 x10^{-06}	32.846	1.14 x10^{-04}	0.7500
F	3	11.8711*	1.32181*	3.71516*	0.11	0.03136*	1.04 x10^{-03*}	204.984*	1.76 x10^{-03*}	17.376*
V	2	10.9172*	3.36025**	4.32731*	0.0475	0.02748*	7.58 x10^{-04*}	166.099**	2.43 x10^{-03*}	15.557*
F*V	6	1.1036*	0.07157*	0.20011*	0.0375	0.00061*	4.75 x10^{-06*}	9.138*	8.45 x10^{-05*}	0.0808*
Error	22	1.0435	0.04255	0.09744	0.22061	0.0009	3.89 x10^{-05}	6.251	1.15 x10^{-04}	1.2991

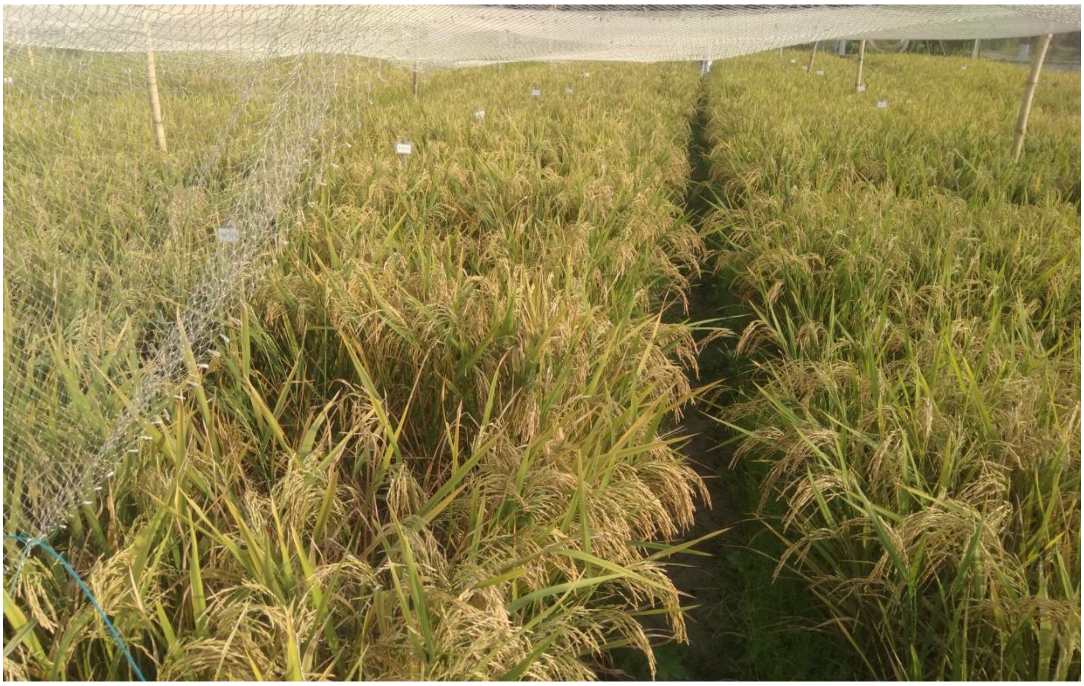
* Significant at 0.05 level
** Significant at 0.01 level



Appendix VI: Image showing view of the experimental field.



Appendix VII: Experimental field visit with supervisor



Appendix VIII: Image showing experimental field prior to harvesting

Appendix IX: Image showing panicle of BRRI dhan81

Appendix X: Image showing post harvest data collection.

Appendix XI: Image showing post harvest soil sampling from the experimental field.