EFFECT OF ORGANIC AND INORGANIC PHOSPHORUS ON THE PERFORMANCE OF MODERN T. AMAN RICE

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CERTIFICATE

This is to certify that the thesis entitled " **EFFECT OF ORGANIC AND INORGANIC PHOSPHORUS ON THE PERFORMANCE OF MODERN T. AMAN RICE**" 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 *r*esearch work carried out by **ISMAT NIGAR LIZA**, Registration No. **18-09264** 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.

Date:
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Dedicated to

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka from June to December 2019 to investigate the comparative performance of organic and inorganic phosphorus and to find out the best combination for better performances of modern wet season rice varieties. The experiment consisted two factors, Factor A: Two rice varieties viz: V_1= BRRI dhan71 and V_2= BRRI dhan72; and Factor B = Five nutrient treatments viz: T_1= N_{85}+ P_0 + K_{55} + S_{12} + $Zn_{1.2}$; T_2= T_1 + $P_{15\ (\text{from TSP})}$, T_3 = T_1 + $P_{15\ (\text{from DAP})}$, T_4= T_1+ $P_{15\ (\text{from TSP})}$ + Poultry manure 3.7 t ha^{-1}, and T_5 = T_1 +$P_{15\ (\text{from DAP})}$ + Poultry manure 3.7 t ha^{-1}. The experiment was laid out in split plot design with three replications. Uniform and standard management practices were followed for all the treatments and varieties. The treatments, varieties and their interactions had significant effects on growth parameters, yield and yield components of .BRRI dhan72 produced the statistically higher mean grain yield (6.30 t ha^{-1}) compared to BRRI dhan71 (5.36 t ha^{-1}). Among the treatments, the highest mean grain yield (6.60 t ha^{-1}) was obtained in T_5 followed by T_4(6.15 t ha^{-1}) and the lowest mean grain yield (4.65 t ha^{-1}) was found in T_1.and BRRI dhan72 produced the highest grain yield (7.10 t ha^{-1}) in combination with the treatment T_5 that was followed by BRRI dhan72 with T_4 (6.40 t ha^{-1}) and the lowest grain yield (3.80 t ha^{-1}) was found in BRRI dhan71 with T_1. The highest grain yield (6.10 t ha^{-1}) of BRRI dhan71 was attained along with T_5. Growth parameters, yield components, straw yield and harvest index of both the varieties were followed the similar trend of grain yield. Both the rice varieties BRRI dhan72 and BRRI dhan71 gave their highest performances when applied fertilizers of the treatment T_5. Therefore,it could be concluded that the treatment T_5 (N_{85} + $P_{15(\text{from DAP})}$+K_{55}+S_{12}+$Zn_{1.5}$ + Poultry manure 3.7 tha^{-1}) would be recommended for T. Aman rice to attain higher yield and better performance.

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ABBREVIATIONS AND ACRONYMS

N : Nitrogen
P : Phosphorus
K : Potassium
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 completely blocked design
S : Sulfur
CEC : Cation exchange capacity
meq : Milliequivalents

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food for the people of Bangladesh (Zaman, 2000) and it is the staple food for more than two billion people in Asia (Myint *et al*., 2010) and it provides 21% and 15% per capita of dietary energy and protein, respectively (Maclean *et al*., 2002). In Bangladesh the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. However, the national average rice yield in Bangladesh (4.2 t h^{-1}) is very low compared to those of other rice growing countries, like China (6.30 t h^{-1}). Japan (6.60 t h^{-1}) and Korea (6.30 h^{-1}) (FAO. 2009). The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. Rice production vastly depends on the availability of nutrients from the soil. Nitrogen, phosphorus and potassium are the three primary nutrient element for rice growth. Deficiency of these elements during crop growth can limits the yield and yield contributing characters of rice.

Phosphorus (P) is an important plant nutrient for all crops and component of nucleic acid, phytin and phospholipids. It is a key constituent of Adenosine Di-phosphate (ADP) and Adenosine Tri Phosphate (ATP) and plays significant role in the energy transformation in plants (Sanker *et al*., 1984). It plays vital role in cell division, flowering, and fruiting including seed formation, crop maturation, root development and quality improvement. Many soils of the Indo-Gangetic plain, including Bangladesh have become P deficient (BRRI, 1992). Depleted soil fertility is a major constrain to higher crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrient in soils. The farmers of this country use on an average 102 kg nutrients ha^{-1} annually (70 kg N + 24 kg P + 6 kg K + 2 kg S and Zn) while the crop removal is about 200 kg h^{-1} (Islam at el., 1994). In Bangladesh, most of the cultivated soils have less than 1.5% organic matter while a good agricultural soil should contain at least 2% organic matter (Ali, 1994). Moreover, this important component of soil is declining with time due to intensive cropping and use of higher dose of chemical fertilizers with little or no addition of organic manure in the farmer's field. In addition, rapid mineralization of soil organic matter ocean due to humid tropic climatic conditions of Bangladesh. Rice yield in P deficient soil was less than 50% of that obtained from soils containing even moderate levels of P (Saleque *et al*., 1998). Much of the P applied to soils as fertilizer become fixed into unavailable forms to plant (Choudhury *et al*., 2007), leading to agronomic and economic inefficiency. Phosphorus fertilizer management is complex as it requires knowledge of the supply of other nutrients to crop, the overall P balance in soil, the effective P supply from indigenous soil resources, fertilizer application, crop P export and recycling, and the processes that govern the availability of P in a particular soil (Doberman *et al*., 1996). The amount of soil P removed by crops needs to be replenished through the application of fertilizer to maintain soil P balance. The crucial fact about P application to agricultural soils is that an under dose will impede crop growth, while an overdose will be wasteful and also pose an environmental threat of eutrophication (Sharpley *et al*., 2001). 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). The integrated nutrient management comprises the integrated use of fertilizers from organic and inorganic sources and their management for efficient and economic use and maintenance of soil fertility and productivity (Prasad and Rovima, 1991). To get maximum yield combination of organic and inorganic fertilizer is the best option.

The major possible sources of organic manures are cowdung (CD), poultry manure (PM) and household wastes (HW) which can be used as an alternative for the inorganic fertilizer. Nutrients contained in organic manures are released slowly and are stored for longer time in soil, thereby ensuring a long residual effect, supporting better root development, leading to higher crop yields. The soil fertility status is improved by activating the soil microbial biomass. Poultry manure is an organic manure which is rich in phosphorus content (Almeida *et* *al*., 2019; Hoover, 2015; Bolan *et al*., 2010 and Kaiser, 2006). Poultry manures have been used as natural crop fertilizers for centuries. Because of poultry manure's high nutrient content, it has long been recognized as one of the most desirable manures (Davis *et al*., (1992). Poultry manure (PM) contains a large proportion of phosphorus (P) in mineral-associated forms that may not be readily available for plant uptake. In addition, PM application influences both chemical and biotic processes, and can affect the lability of native soil P (Waldrip *et al*., 2011). Application of poultry manure in combination with inorganic fertilizers can increase the productivity of rice as well as can improve the soil chemical and physical properties and nutrients content (Ilma *et al*., 2012 and Vanjau and Raju, 2002). Supply of nutrients from the organic materials can be complemented by enriching them with inorganic nutrients that will be released fast and utilized by crops to compensate for their late start in nutrient release. In Bangladesh, most of the cropping patterns are rice-based and the soils are deficient in P and other macro and micro nutrients.

Organic manure can supply a good amount of plant nutrients thus can contribute to crop yields. Thus, it is necessary to use fertilizer and manure in an integrated way in order to obtain sustainable crop yield without affecting soil fertility. The integrated approach by using the organic and inorganic sources of nutrients helps to improve the efficiency of nutrients. To achieve sustainability and increase nutrient use efficiency of rice based cropping pattern it is the demand of time to develop an organic and inorganic soil fertilization program for higher crop yield and improve soil health. Considering this, the objectives are-

- To investigate the comparative performance of organic & inorganic phosphorus on growth and yield of modern Aman rice varieties.
- To find out the best combination organic and inorganic sources of phosphorus for better performances of modern wet season rice varieties.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Effects of phosphorus on growth and yield of rice

Srivastava *et al.* (2014) carried out an experiment on basmati rice–wheat rotation with combinations of Zn levels (0, soil application of 2.5 kg Zn ha$^{–1}$ and two foliar applications of 2.0 kg Zn ha $^{–1}$) and P levels (0, soil application of 8.7, 17.5 and 26.2 kg P ha$^{–1}$). The highest pooled grain yields of basmati rice and wheat were obtained with soil application of 17.5 kg P ha$^{–1}$ and foliar applications of 2 kg Zn ha$^{–1}$.

Yosef (2013a) investigated the effect of nitrogen and phosphorus fertilizer on growth and yield in rice cultivar Tarom Hashemi, where phosphorus fertilizer was used at 4 level 0 (control), 30, 60 and 90 kg ha$^{–1}$ as sub plot. Tiller production was also highly responsive to phosphorus levels. Maximum fertile tiller percentage (%) was (79.54) observed for 90 kg ha$^{–1}$ phosphorus fertilizer and minimum of that was (66.73) 6 obtained for (control) 0 kg ha$^{–1}$ phosphorus fertilizer. Maximum barrier tiller was (8.15) observed for (control) 0 kg ha$^{–1}$ P fertilizer and minimum of that was (5.36) obtained for 90 kg ha$^{–1}$ phosphorus fertilizer. Barrier tiller percentage (%) under phosphorus fertilizer treatment in P1 to P4 was (33.27), (28.72), (25.45) and (20.46) respectively. The effective tillers hill$^{–1}$ of rice verities also varied significantly due to P fertilizer application, plant grown without P fertilizer had the lowest effective tillers hill$^{–1}$, rice plants to accelerate the phosphate absorption for increased tillering. Maximum grain yield was (4540) observed for 90 kg ha$^{–1}$ phosphorus fertilizer and minimum of that was (3800) obtained for (control) 0 kg ha–1 phosphorus fertilizer.

Yosef (2013b) observed that the effect of phosphorus fertilizer on spikelet number and yield was significant in 1% probability level. Fertile spikelet, fertile spikelet percentage (%), sterile spikelet percentage (%) and biological yield were significant in 5% probability level. Spikelet number under phosphorus fertilizer treatment in P_1 to P_4 was (89.63), (90.54), (96.67) and (97.41), respectively. Increasing the levels of P up to 26.4 kg ha-1 also significantly increased ($p<0.01$) the number of spikelets panicle^{-1}.

Rasavel and Ravichandran (2013) carried out field experiments to study the interaction of phosphorus, sulfur and zinc on growth and yield of rice in neutral and alkali soils by and observed that the highest plant height (89.5, 52.8 cm), number of tillers hill^{-1} (17.2, 16.3), LAI (5.89, 5.12), chlorophyll content (4.58, 4.16 mg g^{-1}), DMP (8436, 7385 kg ha^{-1}), panicle length (24.9, 21.6 cm) and number of grain panicle^{-1} (115.6, 108.3) was noticed with application of 50 kg P_2O_5 ha^{-1}, 20 kg S ha^{-1} and 10 kg Zn ha^{-1} (T_8) in neutral and alkali soils respectively. It was superior to rest of the treatment combinations except T_{16} (50 kg P_2O_5 ha^{-1}, 40 kg S ha^{-1} and 10 kg Zn ha^{-1}). The growth was reduced at the highest level of P, S and Zn applied. The highest grain (5216, 4678 kg ha^{-1}) and straw yields (6123, 5642 kg ha^{-1}) was noticed with application of 50 kg P_2O_5, 20 kg S and 10 kg Zn ha^{-1} in neutral and alkali soils respectively. This was comparable with 50 kg P_2O_5, 40 kg S and 10 kg Zn ha^{-1}. For given level of phosphorus and sulfur, increasing levels of zinc improved the grain yield by 2.5 to 15.3 per cent. However, when all the three nutrients were applied at highest level, yield reduction was noticed. Increasing phosphorus doses significantly increased the yield attributes and yield over control. The rate of increase in grain yield with each successive increment in P dose was more than that in straw yield.

Dinesh *et al*. (2012) carried out an experiment at Research Farm of College of Agriculture, Kaul (Kaithal) Chaudhary Charan Singh Haryana Agricultural University, Hisar during kharif season of 2010 on clay loam alkaline soil, low in organic carbon and available nitrogen, medium in phosphorus and high in potassium. He found that increasing NP levels significantly increased all the crop growth parameters viz. plant height, tillers m^{-2}, dry matter accumulation. The yield contributing characters (panicles m^{-2}, grains panicle^{-1}), yield (grain and straw), net profit and benefit cost ratio were higher with N: 90, P: 45 kg ha^{-1}.

lqbal (2004) carried out an experiment on interactions of N, P and water application and their combined effects on biomass and yield of rice. It was concluded that the yield of rice increased by 50-60% in response to the application of N and P interaction with H_20.

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

Islam *et al*. (2010) conducted a field experiment for five phosphorus rates (0, 5, 10, 20 and 30 kg P ha^{-1}) were tested with four rice genotypes in Boro (BRRI dhan36, BRRI dhan45, EH1 and EH2) and T. Aman (BRRI dhan 30, BRRI dhan 49, EH1 and EH2) season. Phosphorus rates did not influence grain yield irrespective of varieties in T. aman season while in Boro season P response was observed among the P rates. Application of P @ 10 kg ha^{-1} significantly increased the grain yield. But when P was applied @ 20 and 30 kg P ha^{-1}, the grain yield difference was not significant. The optimum and economic rate of P for T. Aman was 20 kg P ha^{-1} but in Boro rice the optimum and economic doses of P were 22 and 30 kg ha^{-1}, respectively. Hybrid entries (EH1 and EH2) used P more efficiently than inbred varieties. A negative P balance was observed up to 10 kg P ha^{-1}.

Talukder *et al*. (2010) conducted field experiments to examine the effects of water management (WM) and Phosphorus (P) rates on as uptake and yields in rice. There were 6 treatments consisting of two tillage options [Permanent raised bed PRB (aerobic WM) and conventional till on flat-CTF (anaerobic

WM)] and three P levels (0%, 100% and 200% of recommended P) using two rice varieties, in an As-contaminated field at Gaibandha, Bangladesh in 2004 and 2005. Significantly, the highest grain yields (6.65 and 7.12 tha^{-1} in winter season irrigated rice (boro) 6.36 and 6.40 t ha^{-1} in monsoon rice (aman) in both the years' trials) were recorded in PRB (aerobic WM: Eh = + 360 mV) plus 100% P amendment. There was a 14% yield increase over CTF (anaerobic WM: Eh = -56 mV) at same P level.

Alam *et al*. (2009) carried out a field experiment at the Agronomy Field of the Sher-e-Bangla Agricultural University, Dhaka during December 2006 to June 2007 to study the relative performance of inbred and hybrid rice varieties at 9 different levels of phosphorus (P). Three varieties of inbred and hybrid rice and five levels of P (0, 24, 48, 72 and 96 kg P_2O_5 ha^{-1}) were used as treatment. Number of tillers hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, spikelet sterility, 1000-grain weight, grain yield and straw yield differed significantly with the application of P fertilizer while harvest index did not vary significantly. Phosphorus at 72 kg ha^{-1} (P_3) produced the highest grain yield (7.23 t ha^{-1}) of rice. Plants grown without added P gave the lowest grain yield (4.99 t ha^{-1}).

Dunn and Stevens (2008) conducted a field experiment to evaluate the effect of polymer coating of phosphate fertilizer on rice yield. Three rates of phosphate fertilizer, including polymer coated and non-coated, were compared to an untreated check. Net return was calculated based on crop price and input costs. At the rate of 25 lb/acre P_2O_5 rate the polymer coated treatments produced greater yields than equivalent non coated treatments.

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

Das and Sinha (2006) conducted a field experiment on sandy loam soil during the kharif season of 2000 to study the effects of the integrated use of organic manures and various rates of N (urea) on the growth and yield of rice cv. IR 68. Among the different sources of organic amendments, farmyard manure (FYM; 10 t ha^{-1}) was superior, followed by the incorporation of wheat straw (5 t ha-1) along with the combined application of phosphates rock (40 kg P_2O_5 ha^{-1}) and N. Grain and straw yields were highest when FYM was applied with 90 kg N ha^{-1}, although this treatment was comparable with combined application of wheat straw, phosphate rock and 90 kg N ha^{-1}.

Zhar *et al*. (2005) conducted an experiment to study the effects of agricultural production on P losses from paddy soils. This implied that runoff P losses would be greatly increased in 10-20 years as a result of the accumulation of soil P if 50 kg P ha^{-1} is applied each year.

Xu-Da *et al*. (2005) conducted pot and field experiment to study the effects of N fertilizer application time and N, P. K fertilizer management on grain amylase content and RVA profile parameters in rice cultivars. Result showed that P fertilizer had influenced on the amylase content.

He-Yuan *et al*. (2004) carried out an experiment to study the effects of soil moisture content and phosphorus application on phosphorus nutrition of rice cultivated in different water regime systems. The P application rates had greater effect on the P nutrition of rice than the soil moisture content.

Iqbal (2004) carried out an experiment on interactions of N, P and water application and their combined effects on biomass and yield of rice. It was concluded that the yield of rice increased by 50-60% in response to the application of N and P interaction with H_2O.

Nair and Rajasree (2004) conducted a field experiment to assess comparative efficiency of super phosphate and PR (34/74) at different levels in the yield characters and composition of rice. The treatments were 30 and 45 kg P_2O_5 ha^{-1} in the form of superphosphate and PR (34/74) with and without organic matter. The results showed that high grade phosphate rock (M, 34/74) with organic manure performed well and were followed by PR (34/74) with iron pyrites and green manure. Thus, PR (34/74) performed well with organic matter, FeS2 and green manure in deciding growth and yield of rice. Higher contents of N, P, K, Ca and Mg of grain and straw were obtained at higher levels of 45 kg P_2O_5 ha^{-1} treatment.

Pheav *et al*. (2003) conducted an experiment and seen that freshly applied P increased rice grain yield by 95%. In the first and second crops using residual P fertilizer, yields increased by 62 and 33% relative to the nil-P plot. Grain yields in the third crop using residual P dropped to levels obtained in the nil-P soils.

Khandaker (2003) conducted an experiment at the BRRI, Gaizpur during boro season to determine the optimum rate and effect of different time of P application on the growth and yield of rice. Phosphorus application enhanced all the growth parameters and increased the grain and straw yields. Application of P @ 30, 45, 60 and 75 kg ha^{-1} exerted more or less similar effects on growth parameters. Phosphorus application @ 30 kg ha^{-1} produces statistically similar grain and straw yields as well as the total yield compared to those with 45, 60 and 75 kg ha^{-1}, respectively but superior to the plants treated with P @ 15 kg ha^{-1} and the control.

Tripathi *et al*. (2001) conducted a pot experiment to study the effects of various levels of P on the grain and straw yields. They concluded that increasing levels of P significantly enhanced the yield.

Kumar and Singh (2001) reported that the significant response of rice to P was observed only up to 26.2 kg P ha^{-1} and application of P in all seasons recorded maximum rice equivalent yield (79.6 q ha^{-1}) which was at par with treatment receiving P in both year rabi (70.8 q ha^{-1}) and treatment receiving P in first year kharif and rabi (70.8 q ha^{-1}).

Sahrawat *et al*. (2001) conducted a field experiment for six years (1993-1998) to determine the response of four promising upland rice cultivars with 0, 45, 90, 135, and 180 kg/ha as triple super phosphate (TSP). Only once used in 1993 and its residual value in 1994, 1995, 1996 and 1998 stated that grain yields of the rice cultivars were significantly increased by fertilizer P in 1993 and by the fertilizer P residues in the subsequent years although the magnitude of response decreased rapidly with time since the fertilizer was not applied.

Chitdeshwari and Savithri (2000) reported that the combined use of organic and inorganic phosphate fertilizer on yield and P status of rice. They obtained highest yield applying 100% of recommended P (SSP) and green manure @6.25 t hi^{-1}. Chowdhury (1996) carried out an experiment in BAU farm to study the effect of different pesticides with recommended doses of NPK (100 kgN ha^{-1}, 60 kgP_20_5 ha^{-1} and 40 kg K_20 ha^{-1}) fertilizers on the growth, yield and mineral composition at tillering and harvesting stages of two varieties of transplanted Anian rice (BR II and Nizershall). He reported that nutrients like N. P, K were found to be in higher amount at tillering stage of plant and decreased with the age.

2.2 Effects of phosphorus containing inorganic fertilizer on rice

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

Amin *et al*. (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of NPK increase Plant height.

Saha *et al*. (2004) conducted an experiment in 2002-2003 to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one check plot. Results show that the application of different packages estimated by different fertilizer models significantly influence panicle length, panicle numbers, spikelet number per panicle, total grains panicle^{-1}, number of filled grain and unfilled grain per panicle. The combination of NPK that gives the highest result was 120-13-70-20 kg ha^{-1} NPKS.

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

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

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

Haq *et al*. (2002 a) reported that the number of panicles increased with increase in the nitrogen rates and that number of panicles per plant increased with increase in NPK rates.

Duhan and Singh (2002) reported that the rice yield and uptake of nutrients increased significantly with increasing N levels. Moreover, the application along with various green manures (GM) showed additive effect on the yield and uptake of micronutrients. Under all GM treatments, the yield and uptake were always higher with 120 kg ha^{-1} than with lower level of nitrogen.

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

2.3 Effect of inorganic and organic fertilizers application on crop production

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.

Miah *et al*. (2004) found 5.6-6 t/ha-grain yields with application of 2 t ha^{-1} poultry manure plus 120 kg N ha^{-1} in T. Aman season.

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

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.

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.

Channbasavana and Biradar (2001) reported that the application of poultry manure @ 3 t/ha gave 26% and 19% higher grain yield than that of the control 1998 and 1999, respectively.

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.

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

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.

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) mention 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.

Palm *et al*. (1997) found the positive impact of organic fertilizers on soil fertility improvement might be due to the following relationships. First, decomposition and mineralization of nutrients present in the organic material. Secondly, release of some organic acids as a result of organic decomposition which reduces the soil pH, while improving nutrient availability.

Nimbiar (1997) views that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining healthy soil fertility status. Intensive crop production systems have witnessed serious problems associated with loss of soil fertility as a result of excessive soil mining of plant nutrients and consequently reduction in productivity. Application of external source of plant nutrients is a key element in optimal management of soil organic matter, crop residues and manure for ensuring the bio-availability, the cycling and the balance of nutrients in the soil - plant systems.

Mathew and Nair (1997) reported that cattle manure when applied alone or in combination with chemical fertilizer (NPK) increased the organic C content, total N, available P and K in rice soils.

Sarker and Singh (1997) reported that organic fertilizers when applied alone or in combination with inorganic fertilizers increase the level of organic carbon in soil as well as the total N, P and K contents of soil.

Xu *et al.* (1997) observed that application of organic matters affect soil pH value as well as nutrient level. Santhi *et al*. (1999) observed that application of 100% NPK plus FYM decreased the bulk density and increased the water holding capacity of soil. The decreased in bulk density in FYM treated plots might be ascribed to better aggregation. The 14 water holding capacity was increased due to the improvement in structural condition of soil that was brought about mainly by the application of FYM in combination with NPK fertilizers.

Palm *et al.* (1996) stated that organic materials influence nutrient availability nutrients added through mineralization – immobilization pattern as energy sources for microbial activities and as precursors to soil organic matter and by reducing P sorption of the soil.

Medhi *et al.* (1996) reported that incorporation of organic and inorganic sources of N increased soil solution NH_4-N to a peak and then declined to very low levels.

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

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

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

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

Bair (1990) stated that sustainable production of crop can’t be maintained by using chemical fertilizers only and similarly it is not possible to obtain higher crop yield by using organic manure alone. Sustainable crop production might be possible through the integrated use of organic manure and chemical fertilizers.

2.5 Poultry manure as source of organic phosphorous

Almeida et al. (2019) said that poultry litter provides an important source of plant nutrients including nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The potential for phosphorus (P) surplus at the farm scale can increase when farming systems change from cropping to intensive poultry and animal production, as P inputs become dominated by poultry and animal feed rather than fertilizer. To test the hypothesis that indicates the quantity of animal manure (AM) depends on the phosphorus (P) needs of the crops, an experiment was run using three organic animal manures (chicken- CM, turkey- TM, and cow manure- CoM), enriched with limestone, gypsum, and phosphorus. A greenhouse experiment was run using AM incorporated in a clayey soil, at a rate that equates to the P needs of *Brachiaria* sp. Contents of phosphorus, potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), organic matter (OM), and values of pH and cation exchange capacity (CEC) were monitored during 120 days. Plants were collected to determine the dry matter. It was found that Application of enriched AM increased the contents of Ca, Mg, and K over time, while P and OM presented a decrease. Soil fertilized with CoM resulted in the greatest contents of P and OM, while soil with TM presented the highest production of dry matter with the lowest contents of P in soil. There was an increase in Na content in soil with the application of AM. Fertilization with AM presents the potential to supply P, Ca, Mg and K for plants. Enriched CoM appears to be the most viable option to improve the phosphorus and organic matter in soil because of high C/N. However, farmers may need to pay attention to the quantity of Na.

Bolan et al., 2010. Stated that, the major plant nutrients in poultry litter include nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The total N and P contents of poultry manures and litters are among the highest of animal manures; the total N and P contents are usually lower for poultry litter than for fresh manure, reflecting both the losses that occur following manure excretion and the dilution effect from combining manures with carbonaceous bedding materials that are very low in N and P. Among the various nutrients in poultry litter, N and P cause some environmental concerns. Phosphorus in poultry litter is present mainly in solid-phase as organic and inorganic P. The amount of total P in poultry litter varies with the diet and bedding material, and ranges from 0.3 to 2.4 % of dry matter. Fractionation studies have shown that a large proportion of P in poultry litter is in acid soluble fraction, indicating low bioavailability. Mineral species, such as struvite ($MgNH_4PO_4.2H_2O$), octocalcium phosphate ($Ca_4H(PO_4)_3.3H_2O$) and dicalcium phosphate ($CaHPO_4.2H_2O$) have been identified in the solid fraction of poultry manure.

Hoover (2015) stated that long-term application of manure can lead to phosphorus accumulation in the soil and increase the risk of P delivery to tile drainage waters. A long-term study (1998–2009) was conducted on eight tile-drained field plots, ranging in size from 0.19 to 0.47 ha, to investigate the effects of long-term surface application of poultry manure on soil phosphorus dynamics and PO_4-P loss in tile drainage in Iowa under a corn-soybean rotation system. The experimental treatments included two poultry manure treatments, applied on an N basis at target rates of 168 kg N ha^{-1} (PM) and 336 kg N ha^{-1} (PM_2), each with three replications, and one chemical fertilizer treatment of urea ammonium nitrate (UAN) at a rate of 168 kg N ha^{-1} with two replications. Actual manure application rates and estimated plant available N (PAN) varied annually. Bray1-P methods were used to analyze deep core soil samples at five depths (0–15, 15–30, 30–60, 60–90, and 90–120 cm), which were collected in the spring and fall on the half of each plot planted to corn. The results of this study indicated PM_2 and PM resulted in a statistically significant increase in topsoil P at 0–30 cm, with no significant movement of P to deeper soil depths. Although an increase in topsoil P levels was observed with poultry manure application, average annual tile drainage P concentrations were not statistically different throughout the study with average PO4-P concentrations of 0.019 ppm with PM_2 application and 0.011 and 0.012 ppm for PM and UAN, respectively.

Peirce, *et al*. (2013) conducted a study to compare the bioavailability and P speciation of three manures of different stockpiling duration: less than 1 month, 6 months and 12 months; manures were collected concurrently from a single poultry farm. Results showed that the addition of all manures significantly increased shoot biomass and P concentration, with the fresh manure having the greatest effect. Addition of the fresh manure resulted in the largest labile P pool, highest manure P uptake and manure P recovery, while the manure stockpiled for 12 months resulted in the lowest manure P uptake and manure P recovery. NMR analysis indicated that there was more monoester organic P, especially phytate, in manure stockpiled for shorter periods, while the proportion of manure P that was orthophosphate increased with stockpiling time. Conclusions Together, these results imply that although the proportion of total P in the manures detected as orthophosphate was higher with longer stockpiling, only a fraction of this orthophosphate was plant-available. This suggests the availability of P from orthophosphate in manures decreases with longer stockpiling time in much the same way that P from orthophosphate in mineral fertilizer becomes less available in soil over time.

Waldrip *et al*. (2011) said that poultry manure (PM) contains a large proportion of phosphorus (P) in mineral-associated forms that may not be readily available for plant uptake. In addition, PM application influences both chemical and biotic processes, and can affect the lability of native soil P. To investigate the effects of PM on soil P availability, they grew ryegrass (*Lolium perenne*) in greenhouse pots amended with poultry manure. Soil was sequentially extracted by H_2O, 0.5 M $NaHCO_3$, 0.1 M NaOH, and 1 M HCl, and inorganic P (Pi) and enzymatically hydrolyzable organic P (Poe) were quantitated. Root P concentrations were 37% higher and total P uptake 59% higher with PM application than Control. At week 16, there was 30% more labile-Pi (H_2O- plus $NaHCO_3$-Pi) in the rhizosphere with PM than in Control. Result indicated that increased labile-Pi was due primarily to stimulation of soil phosphatases to mineralize NaOH-Poe. Soil pH increased with PM application and plant growth, and may have promoted P availability by decreasing sorption of Al- and Fe-associated inorganic and organic phosphates. These results demonstrate that whereas PM application may initially increase NaOH and HCl-Pi, these fractions can be readily changed into labile-P and do not necessarily accumulate as stable or recalcitrant P in soil.

Kaiser (2006) studied the effects of poultry manure application rates commonly used by Corn Belt crop producers on corn early growth and early availability of P. Twelve trials were established across Iowa where three rates of P (0, 25, and 50 kg P ha^{-1}) were superimposed on three poultry manure rates (from broilers, egg layers or turkeys) consisting of a non-manured control and two rates that varied between (low 21-63 kg total P ha^{-1} and high 50-123 kg total P ha^{-1}). Corn early growth and P uptake usually were increased by manure and fertilizer P, even in several sites with high initial soil P levels. Analysis of results at each site and for approximately similar rates of poultry manure and fertilizer P across sites provided no evidence that manure or fertilizer differed in increasing early growth or P uptake. Early plant growth and P uptake responses were poorly correlated with soil-test P (STP) measured 5 at the V5-V6 growth stage. The soil tests did not detect a statistically significant soil P increase due to manure or fertilizer P application at some sites due to very high variability. The BP, M3P, and OP tests detected approximately similar manure and fertilizer P effects on STP. However, the WEP test detected manure P effects on soil P only in the few sites where there manure had highest percentage of water-soluble P. Overall, the study did not provide evidence for a difference between poultry manure and fertilizer P at increasing early corn growth and P uptake. Also, the study showed that the WEP soil P test was inferior to the routine P tests at assessing available poultry manure P for corn but could be more appropriate for assessing risk of dissolved P loss after manure application.

Davis *et al*. (1992) stated that animal manures have been used as natural crop fertilizers for centuries. Because of poultry manure’s high nutrient content, it has long been recognized as one of the most desirable manures. The most common procedure for determining the amount of manure to add per acre is to consider the manure’s nitrogen content and the crop’s nitrogen needs. He also stated that poultry manure is high in phosphorus. In areas with high levels of phosphorus as determined by a soil test or in areas where phosphorus movement offsite is a concern (e.g., areas with poor drainage, a high slope, or an adjacent water body), phosphorus rather than nitrogen should determine the manure’s application rate.

CHAPTER 3

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 for 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 (SAU), Dhaka, Bangladesh in Aman season during June to December 2019.

3.2 Description of the experimental site and soil:

3.2.1 Geographical location

The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.4 meter above sea level. The experimental field belongs to the Agro-ecological zone (AEZ) of “The Madhupur Tract”, AEZ-28. 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 site is characterized by high temperature, high humidity and medium 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 June to November 2019 have been presented in Appendix II.

3.2.3 Soil

The soil of the experimental field belongs to the general soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.6-6.2. 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 hill rocks 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. The land was above flood level and sufficient sunshine was available during the experimental period. Initial soil samples from 0-15 cm depth were collected from the experimental field. The soils were analysed in the laboratory of the Department of Soil Science, SAU, Dhaka. The physio-chemical properties of the soil in the experimental field are presented in Table 1 and 2.

Table 1. Morphological characteristics of the experimental field, SAU, Dhaka**.**

Morphology	**Characteristics**
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

Source: (BARC, 2018)

Table 2. Initial physical and chemical characteristics of the soil, of the experimental field, SAU, Dhaka**.**

Characteristics	**Value**
Mechanical fractions:	
% Sand (0.2-0.02 mm)	22.50
% Silt (0.02-0.002 mm)	56.75
% Clay (<0.002 mm)	20.75
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.9
Organic C (%)	0.684
Organic Matter (%)	1.167
Total N (%)	0.067
Available P (mg kg^{-1})	19.72
Exchangeable K (me 100 g^{-1})	0.133
Available S (mg kg^{-1})	14.34

3.3 Experimental Details

3.3.1 Planting Material

Two high yielding rice varieties BRRI dhan71 and BRRI dhan72 developed by the Bangladesh Rice Research Institute, Gazipur were was used as a test crop. BRRI dhan71 and BRRI dhan72 were released in 2015 for cultivation in Aman season. BRRI dhan71 and BRRI dhan72 were were developed by pedigree selection after crossing of IR55423-01 x IRRI148 and BR7166-4-5-3 x BRRI dhan39, respectively.

The Method of development of this variety is Hybridization. The variety was released in 2014. Planting time of the seedling in seed bed 25 June -5 July and harvesting time is 1-30 November.

3.3.2 Experimental design

The experiment was laid out in a split plot design, where variety is used as main plot and fertilizer treatments as sub plot. There were 2 varieties and five different treatments. Total plot number was 30 where treatments combinations was 10 applied in three replications. The size of each plot was 6 m^2 (3 m x 2 m) and plots were separated from each other by 50 cm levee. There was one m drain between the main plots. For better understanding the layout of the experiment has been presented in Figure 1.

Factor A: Two Varieties

- V_1= BRRI dhan71
- V_2= BRRI dhan72

Factor B: Five fertilizer treatments as follows,

- T_1= N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$
- T_2= T_1+ $P_{15(\text{from TSP})}$
- T_3= T_1 +$P_{15(\text{from DAP})}$
- T_4= T_1 +$P_{15(\text{from TSP})}$ + Poultry manure 3.7 t ha^{-1}
- T_5= T_1+ $P_{15(\text{from DAP})}$ +Poultry manure 3.7 t ha^{-1}

3.3 Crop establishment

3.3.1 Seed collection and sprouting

Seeds were collected from Bangladesh Rice Research Institute (BRRI), Gazipur just 15 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. These were then taken out of water and kept in a gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing within 72 hours.

3.3.2 Seedlings raising

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown 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 land was first opened on 1 July 2019 by a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling.

3.3.4 Fertilizers application

The fertilizers were applied as per treatments. For T1, fertilizers containing N, K, S and Zn were applied @ of 85, 55, 12, and 1.5 kg ha^{-1}, respectively using urea, muriate of potash, gypsum and zinc sulfate. T_1 was applied with no phosphorus fertilizer which is considered as control. At T_2 for 15 kgha^{-1} of phosphorus from TSP was applied. For $T_{3,}$ 15 kgha^{-1} of phosphorus from DAP was applied. For T_4 poultry manure @ 3.7 tha-^{1} with inorganic phosphorus from TSP fertilizer was used. Finally for T_5, poultry manure @ 3.7 t ha^{-1} with 15 kg ha^{-1} of phosphorus from DAP was applied. Full amount of TSP, MOP, gypsum, zinc sulfate and $\frac{1}{3}$ urea were applied basally during the final land preparation. The remaining urea was top dressed in two equal installments at 20 days after transplanting (DAT) and 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

Twenty-five day old seedlings of BRRI dhan71 and BRRI dhan72 were carefully uprooted from the seedling nursery and transplanted on 10 July 2019. Three seedlings hill^{-1} were transplanted following a spacing of 25 cm ×15 cm.

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.

3.3.10 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 on 20 August and 18 September 2019. 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 treatments 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 80-90% 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 m^2 area. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 14%. Yields of rice grain and straw m^{-2} were recorded and converted to t ha^{-1}.

3.5 Recording of Data

- Plant height (cm)
- Tillers hill^{-1}
- Panicles hill^{-1}
- Panicle length (cm)
- Grains panicle^{-1}
- Unfilled spiklets panicle^{-1}
- 1000 grain weight
- Grain yield (t ha^{-1})
- Straw yield (t ha^{-1})
- Harvest index
- Post-harvest soil analysis

Plant height

The height of plant was recorded in centimeter (cm) at the time of maturity stage. Plant height was measured from 12 plants diagonally in each plot. The height was measured from the ground level to the tip of the panicle.

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. 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} were counted from 2 x 2 hill sampling units from three places (12 hills plot^{-1}) diagonally in each plot. 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.

Grains per panicle

The total numbers of filled grain was collected randomly from selected 10 plants of a plot on the basis of grain in the spikelet and then average numbers of filled grains per panicle was recorded.

Sterile spikelet panicle^{-1}

The total numbers of unfilled spikelet was collected randomly from selected 10 plants of a plot on the basis of no grain in the spikelet and then average numbers of unfilled grains per panicle 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 area was 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):

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

(1)

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 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into Micro Kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water.

A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$\% N = (T-B) \times N \times 0.014 \times 100/S$
Where, T = Sample titration (ml) value of standard H_2SO_4
B = Blank titration (ml) value of standard H_2SO_4
N = Strength of H_2SO_4
S = Sample weight in gram
3.7.4 Available phosphorus
Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen et al., 1954). 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 potassium

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).

3.8 Statistical Analysis

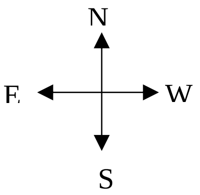
The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of BRRI dhan71 and BRRI dhan72. The mean values of all the characters were calculated and analysis of variance (ANOVA) was performed by the ‘F’ (variance ratio) test using Statistix 10 computer software. The significance of the difference among the treatment means was compared using the Least Significant Difference (LSD) (Gomez *et al*., 1984).

Factor A: variety

V_1: BRRI dhan71
V_2: BRRI dhan72

Factor B: Fertilizer combination

T_1: N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$
T_2: N_{85} $P_{15\text{ (from TSP)}}$ K_{55} $S_{12}Zn_{1.5}$
T_3: N_{85} $P_{15\text{ (from DAP)}}$ K_{55} $S_{12}Zn_{1.5}$
T_4: N_{85} $P_{15\text{(from TSP)}}$) K_{55} $S_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha
T_5: N_{85} $P_{15\text{ (from DAP)}}$ K_{55} $S_{12}Zn_{1.5}$+Poultry manure 3.7 t/ha



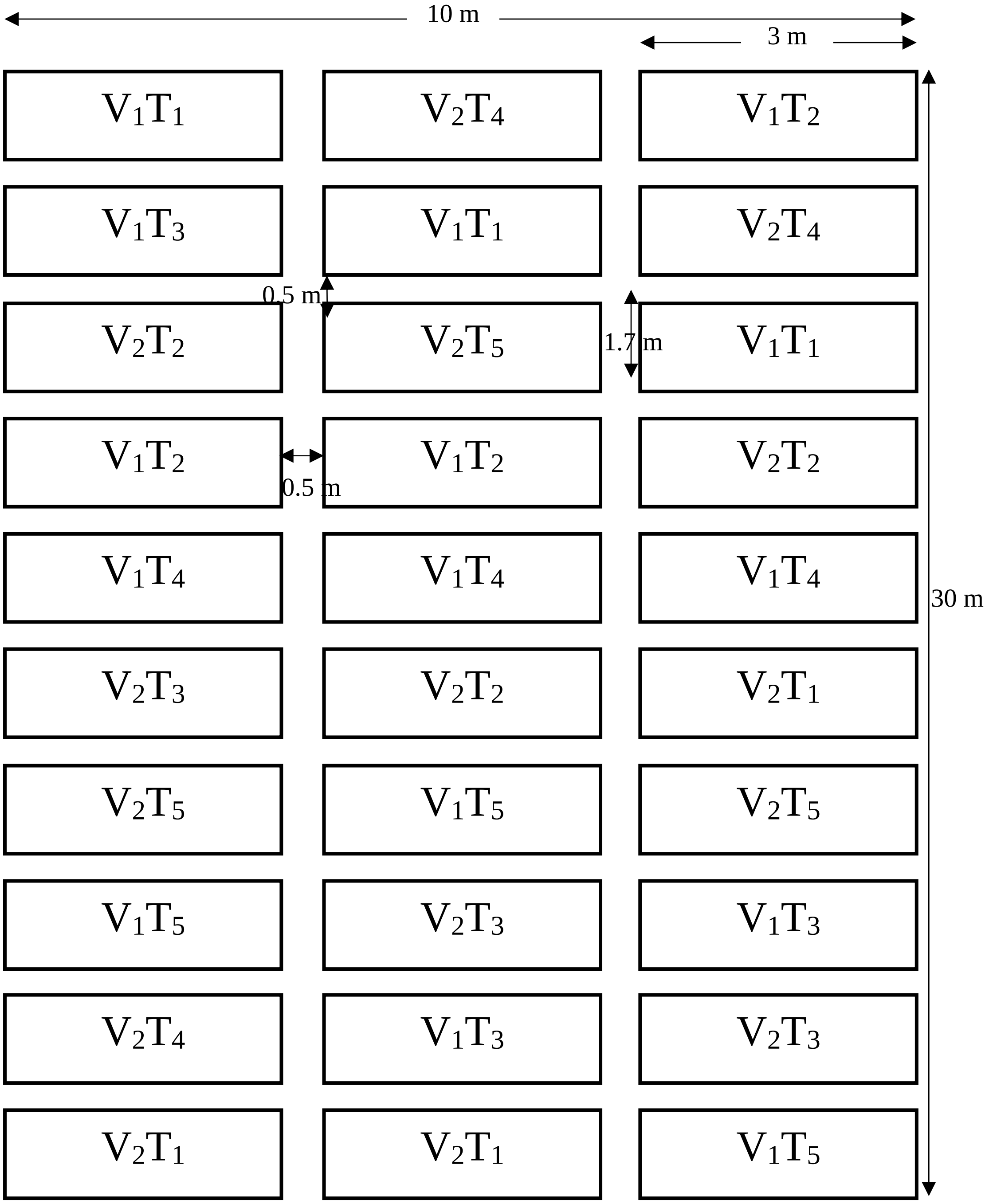


Figure 1: Showing the layout of the experiment

CHAPTER 4

RESULTS AND DISCUSSION

The research work was accomplished to observe the effect of organic and inorganic phosphorus on the performance of modern T. Aman rice (*Oryza sativa* L.) showed differences in terms of different characteristics.

4.1 Plant Height

Plant height was also significantly affected by the genotypes under different fertilizers treatments (Figure 1). . BRRI dhan71 produced the mean tallest plant (111.0 cm) was found in the variety BRRI dhan72 and the shortest plant (101.5 cm) was found in BRRI dhan71 (Figure 1). These results are in good alignments with the findings of Karmakar (2016).

The fertilizers treatments had significant effects on plant height of rice varieties tested in the experiment. The tallest plant (109.7 cm) was found in the treatment T_5 while the shortest plant (101.6 cm) was found in treatment T_1 (Figure 2).

Interaction effects of variety and fertilizers treatments had also significant effects on plant height of the varieties. Plant height varied significantly across the nutrient rates due to genotypic and nutrient effects (Karmakar *et al.*, 2021; Bezbaruha *et al.,* 2011; Rahman, 2011; Zhao *et al.,* 2012). The tallest plant (119.2 cm) was found in the treatment combination of V_2T_5 which was statistically similar with V_2T_3 (113.9) and V_2T_1 (112.1). On the other hand, the shortest plant (91.1 cm) was found in the treatment V_1T_1 which was also statistically similar with V_1T_3 (97.5) (Figure 3).

It was observed the BRRI dhan72 with T_4 which is N_{85} $K_{55}S$ $_{12}$ $Zn_{1.5}$ + Poultry manure 3.7 t/ha performed the best in case of plant height. Inorganic phosphorus containing fertilizer with poultry manure increased the plant height of rice. Similar results were also observed by Reddy *et al*. (2005); Miah *et al*. (2004), and Umanah *et al*. (2003).

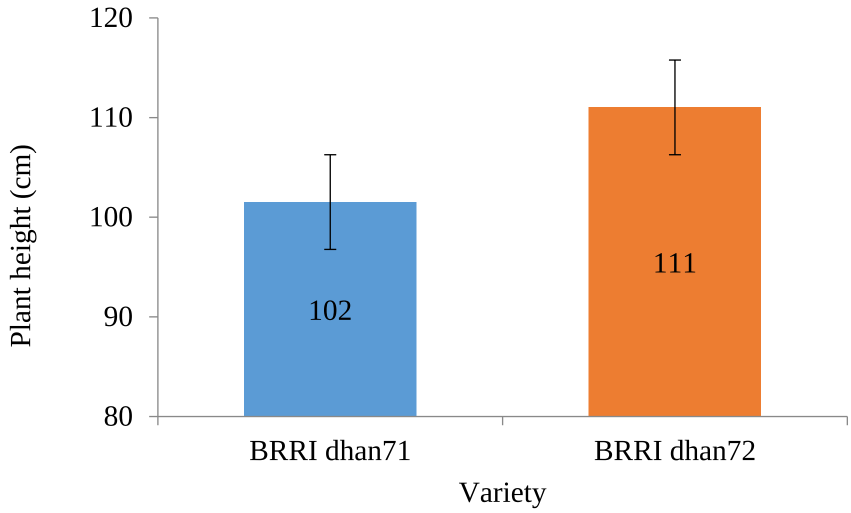


Figure 2. Effect of variety on plant height under different treatments in Aman 2019.

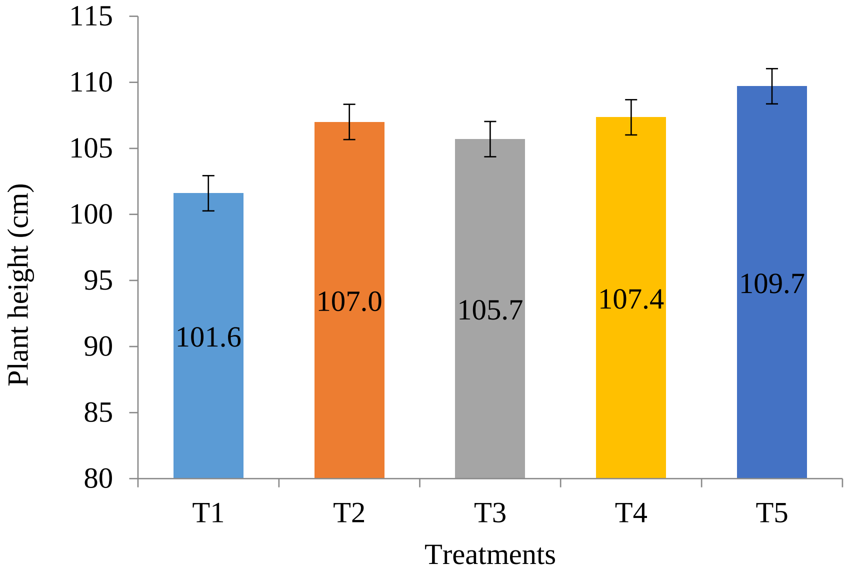


Figure 3. Effect of fertilizers treatments on plant height under different treatments in Aman 2019.

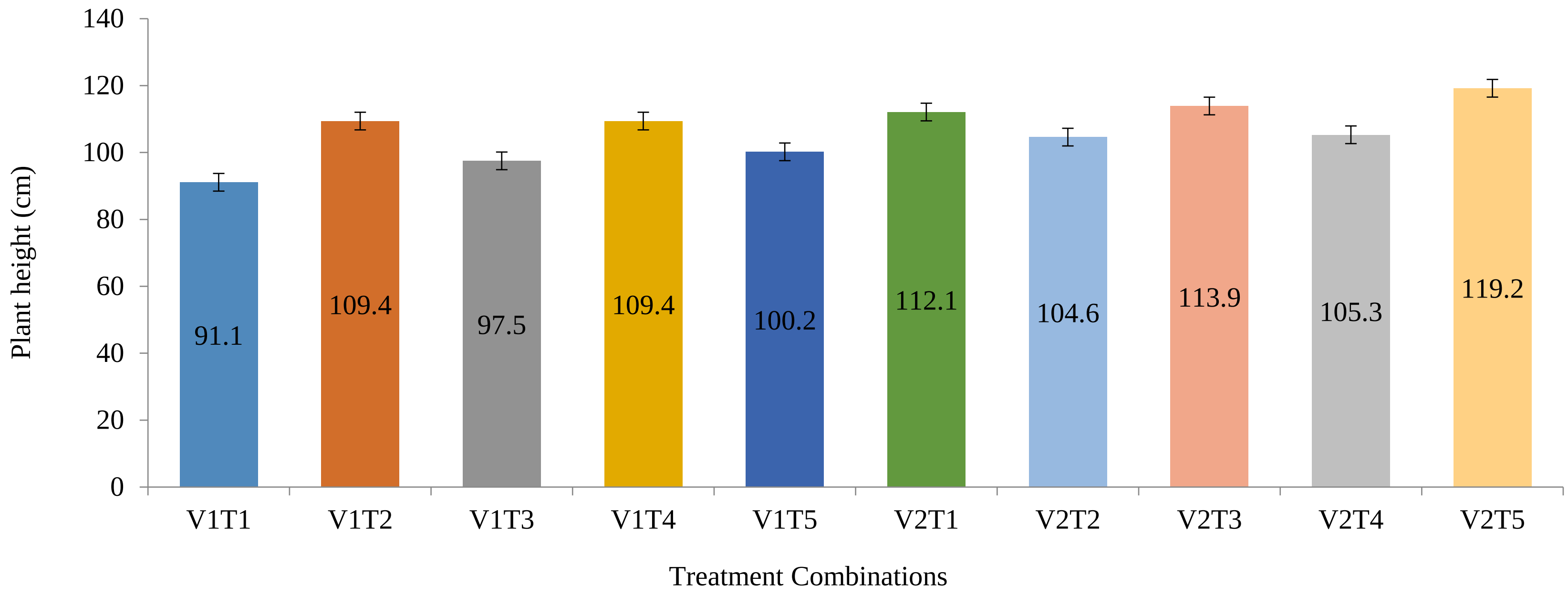


Figure 4. Interaction effect of variety and fertilizers on plant height in Aman 2019.

NB: V_1=BRRI dhan71 and V_2= BRRI dhan72; $T_1 = N_{85} P_0 K_{55} S_{12}Zn_{1.5}$, $T_2 = T_1 + P_{15(\text{from TSP})}$, $T_3 = T_1 + P_{15\ (\text{from DAP})}$, T4 = $T_1 + P_{15(\text{from TSP})}$ + Poultry manure 3.7 t ha^{-1}, and T5 = $T_1 + P_{15\ (\text{from DAP})}$ +Poultry manure 3.7 t ha^{-1}

4.2. Total number of tillers per hill

Significant variation in producing tillers per hill of the varieties were observed at different nutrient levels. Maximum number of tiller per hill (21.2) was found in BRRI dhan72 and the minimum (17.1) was found in BRRI dhan71 (Figure 4).

Total number of tillers per hill of rice plants significantly differed among the different types of fertilizer application. The maximum total number of tiller per hill (21. 5) was found with T_5 treatment and the minimum (17.3) was found in T_1 which was statistically similar with T_2 (18.2) (Figure 5).

There were significant variation among the treatment combinations in case of total number of tillers per hill. The maximum total number of tiller per hill (23.8) was found with V_2T_5 treatment and the minimum was found in V_1T_1 (14.6) (Figure 6).

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 growth which may result in higher number of tiller. Inorganic fertilizers contains high amount of nutrients. On the other hand, poultry manure is a slow releasing nutrient rich organic fertilizer which provides a notable amount of phosphorus with other nutrients. As a result nutrients are available for a long period of time. It also improves the soil structure and texture which provide a better soil environment for better root growth (Hemalatha *et al.* 2000). The results founded by Rahman *et al.* (2010), Choudhury *et al.* (2015) and Islam *et al.* (2011) are supporting to this results.

4.3 Number of panicle per hill

Significant variation was found among the varieties in case of panicle production per hill. Maximum number of panicle per hill was obtained in BRRI dhan72 (17.24) whereas BRRI dhan71 showed minimum number (12.78) of panicle per hill (Figure 4).

The fertilizer treatments significantly affected the tillers and panicle production of the tested varieties. The maximum number of panicle per hill was obtained from treatment T_5 (17.35) while the treatment T_1 (12.3) showed minimum number of panicle per hill (Figure 5).

Significant variation was found among the different types of treatment combinations in case of number of panicle per hill. Maximum number of panicle per hill was obtained in the treatment V_2T_5 (20.6) whereas treatment V_1T_1 showed minimum number (9.1) of panicle per hill (Figure 6).

From this study, it was observed that variety BRRI dhan72 applied with 85 kgha^{-1} N, 15 kgha^{-1} P, 55 kg ha^{-1} K, 12 kgha^{-1} S and 1.2 kgha^{-1} Zn with 3.7 tha^{-1} poultry manure produced maximum number of panicle per hill. On the other hand, number of panicle per hill was minimum in case of BRRI dhan72 with control. Higher the no. of effective tillers produces higher no. of panicles resulted higher yield of the rice varieties. Proper supply of 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. Poultry manure as an organic manure provides better soil condition. Due to this reason, plants produced higher number of panicle of the variety BRRI dhan72 applied with T_5 which is 85 kgha^{-1} N, 15 kgha^{-1} P, 55 kgha^{-1} K, 12 S kgha^{-1} and 1.2 kgha^{-1} Zn with 3.7 tha^{-1} poultry manure. The findings are in alignment with the results obtained by Rahman *et al.* (2010); Choudhury *et al.* (2015) and Islam *et al.* (2011).

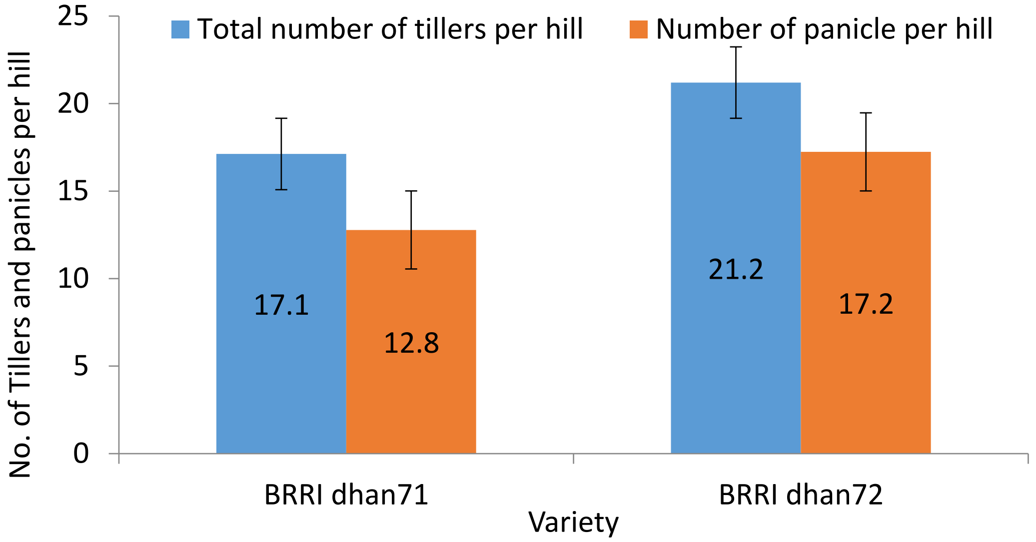


Figure 5. Effect of variety on tillers and panicles per hill under different treatments in Aman 2019.

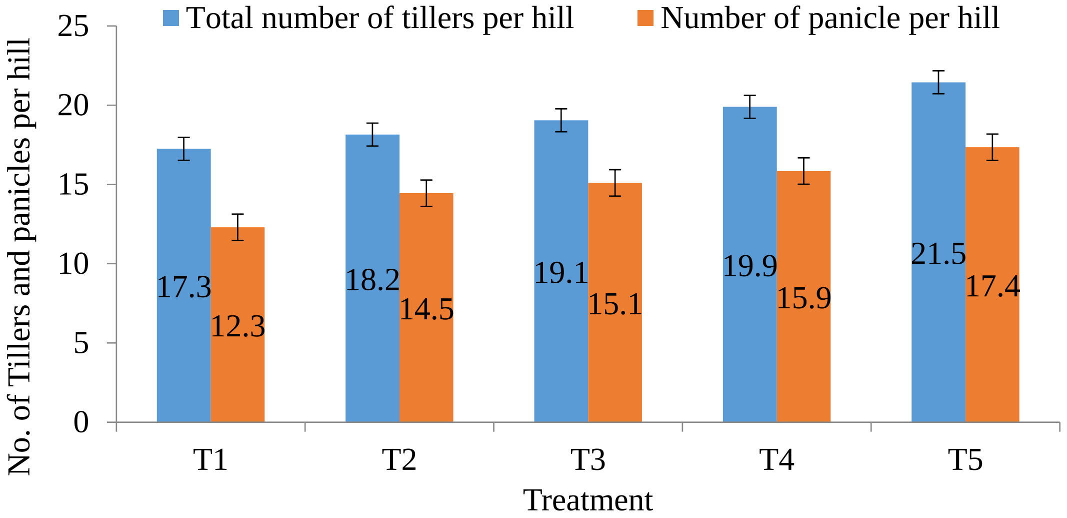


Figure 6. Effect of fertilizers treatments on tillers and panicles per hill under different treatments in Aman 2019.

Note# V_1: BRRI dhan71; V_2: BRRI dhan72; T_1: N_{85} P_0 K_{55} S_{12} $Zn_{1.5}$; T_2: N_{85} P_{15} (from TSP) K_{55} S_{12} $Zn_{1.5}$; T_3: N_{85} P_{15} (from DAP) $K_{55}S$ $_{12}Zn_{1.5}$; T_4: N_{85} P_{15} (from TSP) K_{55} S $_{12}$ $Zn_{1.5}$ +Poultry manure 3.7 t/ha; T_5: N_{85} P_{15} (from DAP) K_{55} S_{12} $Zn_{1.5}$ +Poultry manure 3.7 t/h

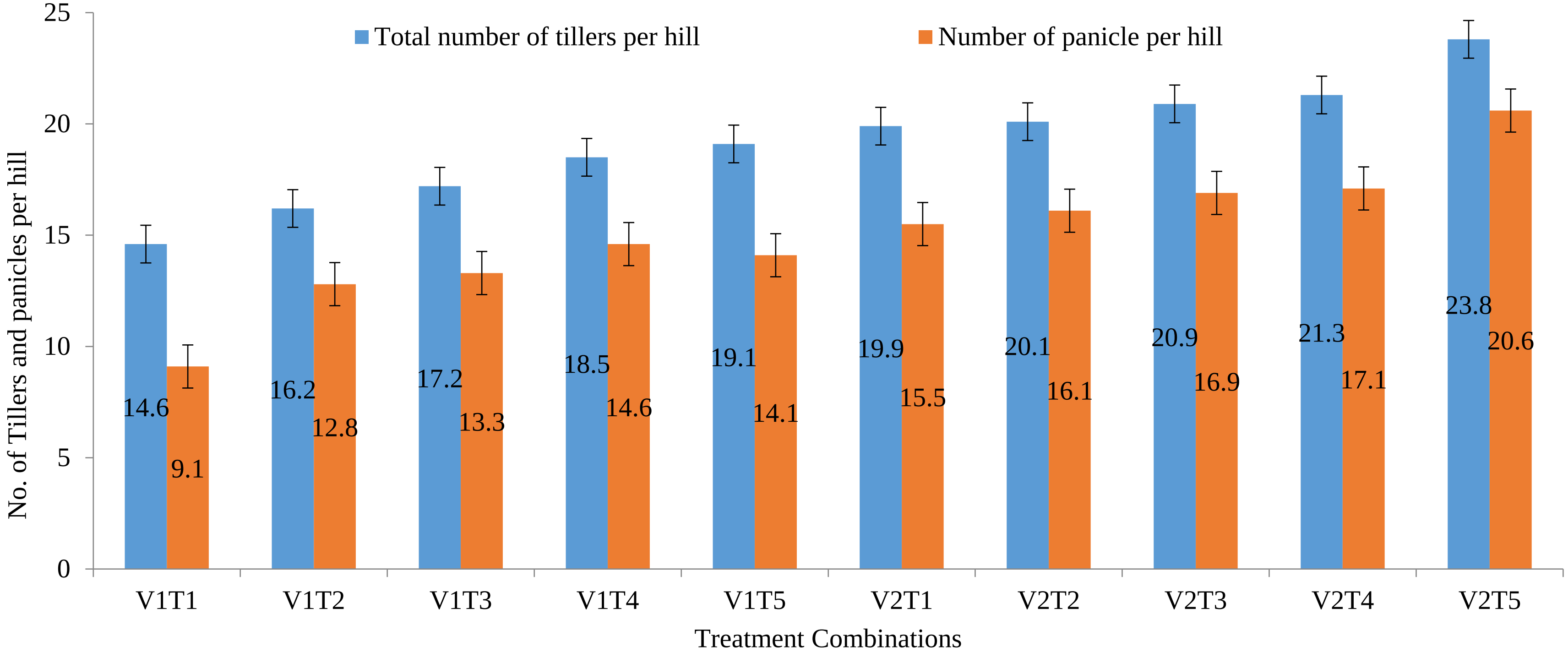


Figure 7. Interaction effect of variety and fertilizers on No. of tillers and panicle per hill.

Note# V_1: BRRI dhan71; V_2: BRRI dhan72; T_1: N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$; T_2: N_{85} $P_{15\ (from\ TSP)}$ $K_{55}S$ $_{12}Zn_{1.5}$; T_3: N_{85} $P_{15\ (from\ DAP)}$ $K_{55}S$ $_{12}Zn_{1.5}$; T_4: N_{85} $P_{15\ (from\ TSP)}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha; T_5: N_{85} $P_{15\ (from\ DAP)}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha

4.4 Panicle length

Rice plants expressed significant difference within the varieties in case of panicle length. From this study it was observed that V_2 (28.6 cm) produced the longer panicle. On the other hand treatment V_1 (23.8 cm) produced the shorter panicle (Table 3).

Rice plants also showed significant difference among the different types of fertilizer application in case of panicle length. It was observed that treatment T_5 (29.6 cm) produced the longest panicle. On the other hand treatment T_1 (23.0 cm) produced the shortest panicle (Table 4).

It was observed that rice plants expressed significant difference among the different types treatments combinations in case of panicle length. Treatment V_2T_5 (33.8 cm) produced the longest panicle. On the other hand treatment T_1 (20.1 cm) produced the shortest panicle (Table 5).

From this research it was observed that applying 85 $kgha^{-1}$ N, 15 P $kgha^{-1}$, 55 $kgha^{-1}$ K, 12 S $kgha^{-1}$ and 1.2 $kgha^{-1}$ Zn with 3.7 tha^{-1} poultry manure to BIRRI dhan72, it had the longest panicle. And where no phosphorus was used produced shortest panicle. Vanjau and Raju (2002) and Channabasavanna (2003) also found this type of result.

4.5 Total number of spikelets per panicle

Total number of spikelets per panicle of rice plants significantly differed among the varieties. Maximum number of spikelets per panicle was found with V_2 (117.9) treatment and the minimum was in V_1 (111.3) (Table 3).

Rice plants also showed significant difference among the different types of fertilizer application in case of total number of spikelets per panicle. It was observed that treatment T_5 (117.9) produced the maximum total number of spikelets per panicle which is statistically similar with T_3 (115.6). On the other hand treatment, T_1 (110.8 cm) produced the minimum total number of spikelets per panicle (Table 4).

Total number of spikelets per panicle of rice plants significantly differed among the different types of treatment combinations. Maximum number of spikelets per panicle was found with V_2T_5 (123.6) treatment which is statistically similar with and the minimum were found in V_1T_1 (106.9) (Table 5).

Study reveals that BRRI dhan72 with T_5 which is N_{85}, K_{55}, S_{12} and $Zn_{1.5}$ + 3.7 tha^{-1} Poultry manure had the maximum total number of spikelets per panicle. Similar findings were observed by Reddy *et al.* (2005); Vanjau and Raju (2002) and Channabasavanna (2003).

4.6 Number of spikelets per panicle

Number of filled spikelets per panicle of rice plants significantly differed among the varieties. Maximum number of filled spikelets per panicle was found with V_2 (88.3) treatment and the minimum were found in V_1 (76.6) (Table 3).

Rice plants also showed significant difference among the different types of fertilizer application in case of number of filled spikelets per panicle. It was observed that treatment T_5 (88.9 cm) produced the maximum number of filled spikelets per panicle. On the other hand treatment T_1 (76.8 cm) produced the minimum number of filled spikelets per panicle (Table 4).

Number of filled spikelets per panicle of rice plants significantly differed among the different types of treatment combinations. Maximum number of filled spikelets per panicle was found with V_2T_5 (96.5) treatment and the minimum was found in V_1T_1 (69.1) which was statistically similar with V_1T_2 (76.5) and V_1T_3 (77.9) (Table 5).

The study reveals that BRRI dhan72 with T_5 which is N_{85}, K_{55}, S_{12} and $Zn_{1.5}$ + 3.7 tha^{-1} Poultry manure had the maximum number of filled spikelets per panicle. Proper nutrient supply at filling stage is very important for spikelets to be filled. Primary nutrients like nitrogen, potassium, phosphorus etc. 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, poultry manure is also rich in these types of nutrients. Poultry manure also contain sufficient amount of organic phosphorus. 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. Islam *et al.* (2011) and Darade and Bankar (2009) found the similar result that inorganic fertilizer in combination with organic fertilizer increases the filled spikelets per panicle.

4.7 Number of unfilled spikelets per panicle

Significant variation was found among the varieties in case of number of unfilled spikelets per panicle. Among the two varieties V_1 (34.7) showed highest number of unfilled spikelets per panicle and treatment V_2 (29.6) showed lowest (Table 3).
Significant variation was also found among the different types of fertilizer management treatments in case of number of unfilled spikelets per panicle. Among the five types of fertilizer management treatments T_1 (34.6) showed highest number of unfilled spikelets per panicle and treatment T_5 (29.5) showed lowest (Table 4).

Significant variation was seen among the different combinations of variety and treatments in case of number of unfilled spikelets per panicle. The combination V_1T_1 (37.8) showed highest number of unfilled spikelets per panicle and combination V_2T_5 (27.1) which was statistically similar with V_2T_4 (28.4), V_2T_3 (30.6), V_2T_2 (30.8) and V_2T_1 (30.9) showed lowest (Table 5).

This study reveals that the plants supplied BRRI dhan71 with no phosphorus produced the maximum 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 Roy (2019); Islam *et al.* (2011) and Darade and Bankar (2009).

4.8 Weight of 1000-grain

Significant variation was found among the varieties in case of weight of 1000-grain. From the study it was found that BRRI dhan72 produced the maximum weight (26.4 g) of 1000-grain. On contrary, BRRI dhan71 produced the minimum weight (24.0 g) of 1000-grain (Table 3).

Significant variation was observed among the different types of fertilizer management treatments in case of weight of 1000-grain. These results are similar to those obtained by Karmakar *et al.*, 2021; Hirzel et al. (2011), and Fageria and Baligar (2001). From the study we found that treatment T_5 (26.1 g) produced the maximum weight of 1000-grain which was statistically similar to T_4 (25.9 g). On contrary, treatment T_1 (23.9 g) produced the minimum Weight of 1000-grain which was statistically similar to T_2 (24.7) (Table 4). 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.

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 V_2T_5 (27.9g) produced the maximum weight of 1000-grain which was statistically identical with T_4 (27.2 g) and statistically similar to T_3 (26.2 g). On contrary, treatment V_1T_1 (23.1 g) produced the minimum Weight of 1000-grain which was statistically similar to V_1T_1 V_1T_2, V_1T_3, V_1T_4, V_1T_5 and V_2T_1 (Table 5).

From this research, it was observed that the variety BRRI dhan72 with N_{85}, K_{55}, S_{12} and $Zn_{1.5}$ + 3.7 tha^{-1} Poultry manure had the maximum weight of 1000-grain and the variety BRRI dhan71 with no supply of phosphorus had the minimum weight of 1000-grain. 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. Islam *et al.* (2011); Darade and Bankar (2009) and Zaman *et al.* (2000) found the similar result that concludes organic and organic fertilizer combination increases grain weight.

Table 3: Effects of Variety on different attributes of rice

Varieties	Panicle length	Total number spikelets per panicle	Number of filled spikelets per panicle	Number of unfilled spikelets per panicle	1000 grain weight
V_1	23.8 b	111.3 b	76.6 b	34.7 a	24.0 b
V_2	28.6 a	117.9 a	88.3 a	29.6 b	26.4 a
LSD (0.05)	0.7	2.6	3.5	2.1	1.1
C. V. (%)	2.8	5.3	4.8	5.1	3.5

Note# V_1: BRRI dhan71, V_2: BRRI dhan72

Table 4: Effects of fertilizer treatments on different attributes of rice

Treatments	Panicle length	Total number spikelets per panicle	Number of filled spikelets per panicle	Number of unfilled spikelets per panicle	1000 grain weight
T_1	**23.0 d**	**110.8 c**	**76.8 c**	**34.6 a**	**23.9 c**
T_2	24.8 c	114.3 b	**80.8 bc**	31.7 b	**24.7 bc**
T_3	26.5 b	**115.6 ab**	82.9 b	31.6 b	25.1 b
T_4	27.1 b	114.6 b	83.4 b	31.4 b	**25.9 ab**
T_5	**29.6 a**	**117.9 a**	**88.9 a**	**29.5 c**	**26.4 a**
LSD (0.05)	1.1	3.2	5.3	2.1	1.8
C. V. (%)	3.5	6.4	5.5	5.5	4.9

Note# T_1: N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$, T_2: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$, T_3: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$, T_4: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha, T_5: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha

Table 5: Interaction effects of Varity and fertilizer treatments on yield attributes of rice

Treatments	**Panicle length**	**Total number spikelets per panicle**	**Number of filled spikelets per panicle**	**Number of unfilled spikelets per panicle**	**1000 grain weight**
V_1T_1	**20.1 f**	**106.9 d**	**69.1 f**	**37.8 a**	**23.1 c**
V_1T_2	23.6 e	111.7 c	**76.5 ef**	34.2 b	**23.6 bc**
V_1T_3	24.5 de	112.6 bc	**77.9 def**	33.7 bc	**23.9 bc**
V_1T_4	25.4 cd	111.3 c	78.5 de	33.6 bc	**24.5 bc**
V_1T_5	25.4 cd	112.9 bc	80.2 cde	31.9 bcd	**24.9 bc**
V_2T_1	25.9 cd	114.3 bc	83.4 bcde	**30.9 cde**	**24.7 bc**
V_2T_2	26.1 c	115.9 bc	85.1 bcd	**30.8 cde**	25.8 b
V_2T_3	28.5 b	118.5 bc	87.9 bc	**30.6 cde**	**26.2 ab**
V_2T_4	28.8 b	117.0 bc	88.6 b	**28.4 de**	**27.2 a**
V_2T_5	**33.8 a**	**123.6 a**	**96.5 a**	**27.1 e**	**27.9 a**
LSD $_{(0.05)}$	1.6	5.1	7.8	3.1	2.3
C. V. (%)	3.5	6.4	5.5	5.5	4.9

Note# V_1: BRRI dhan71; V_2: BRRI dhan72; T_1: N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$; T_2: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$; T_3: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$; T_4: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha; T_5: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha

4.9 Grain yield (t/ha)

Grain yield significantly varied at different levels of nutrients supplied. These results are in alignment with Karmakar *et al.*, (2021) and Zhao *et al.* (2012) who observed that significant genotypic variations existed for grain yield under different nutrient levels that might be due to genotypic variations. Among the varieties, V_2 produced the highest grain yield (6.30 t ha^{-1}) whereas the lowest grain yield was produced by V_1 (5.36 t) (Figure 7).

Grain yield per hectare was significantly affected by different types of fertilizer management treatments. Similar results were confirmed by Karmakar *et al.,* 2021; Artacho et al., 2009; Zhang et al., 2009; Haefele et al., 2008 who reprted that nutrient rates strong significantly ($p<0.01$) influenced the grain yield might be due to disparity of the nutrient amount. Among the all fertilizer treatments, the highest grain yield observed in T_5 (6.60 t) and the lowest grain yield was in T_1 (4.65 t/ha) (Figure 8).

Ineraction effect of varieties and fertilizer treatments on grain yield. These findings are similar to those of Karmakar *et al.,* 2021; Zhao *et al.,* 2012 and Fageria et al., 2010 who found that interactions of genotypes and nutrient rates significantly affected yield and yield components. Among the all treatment combinations, V_2T_5 produced the highest grain yield (7.10 t/ha) while the lowest grain yield (3.80 t/ha) was in V_1T_1 (Figure 9).

From this research it was observed that variety BRRI dhan72 applied with 85 $kgha^{-1}$ N, 15 P $kgha^{-1}$, 55 $kgha^{-1}$ K, 12 S $kgha^{-1}$and 1.2 $kgha^{-1}$ Zn with 3.7 tha^{-1} poultry manure produced the maximum grain yield. On the other hand, BRRI dhan71 with no phosphorus fertilizer nor any poultry manure 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 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. Poultry manure 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. Supply of nutrient with organic matter helps to higher productivity (Zaman *et al.* 2000); Reddy *et al.* (2005); Miah *et al.* (2004), and Umanah *et al.* (2003); Vanjau and Raju (2002); Channabasavanna (2003) and some other researcher also found the similar result

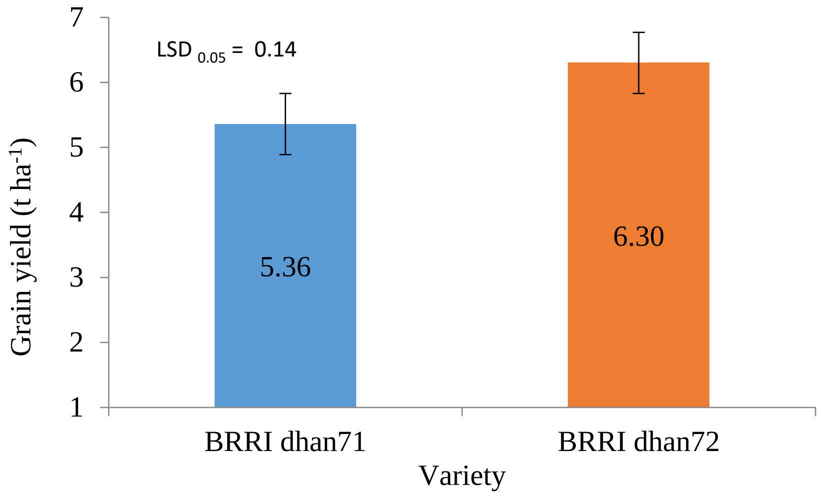


Figure 8. Grain yield of the tested rice varieties at different nutrient levels.

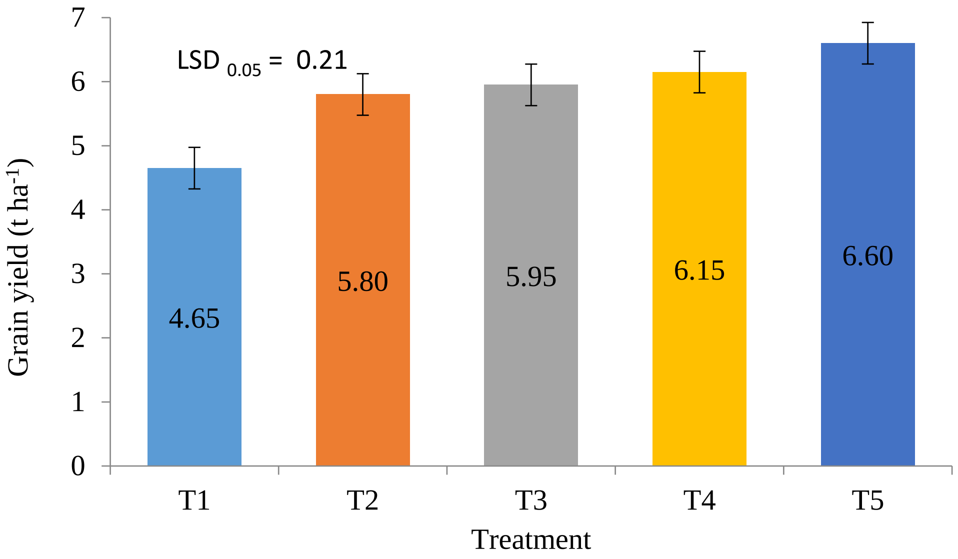


Figure 9. Effect of nutrient treatments on grain yield of the rice varieties

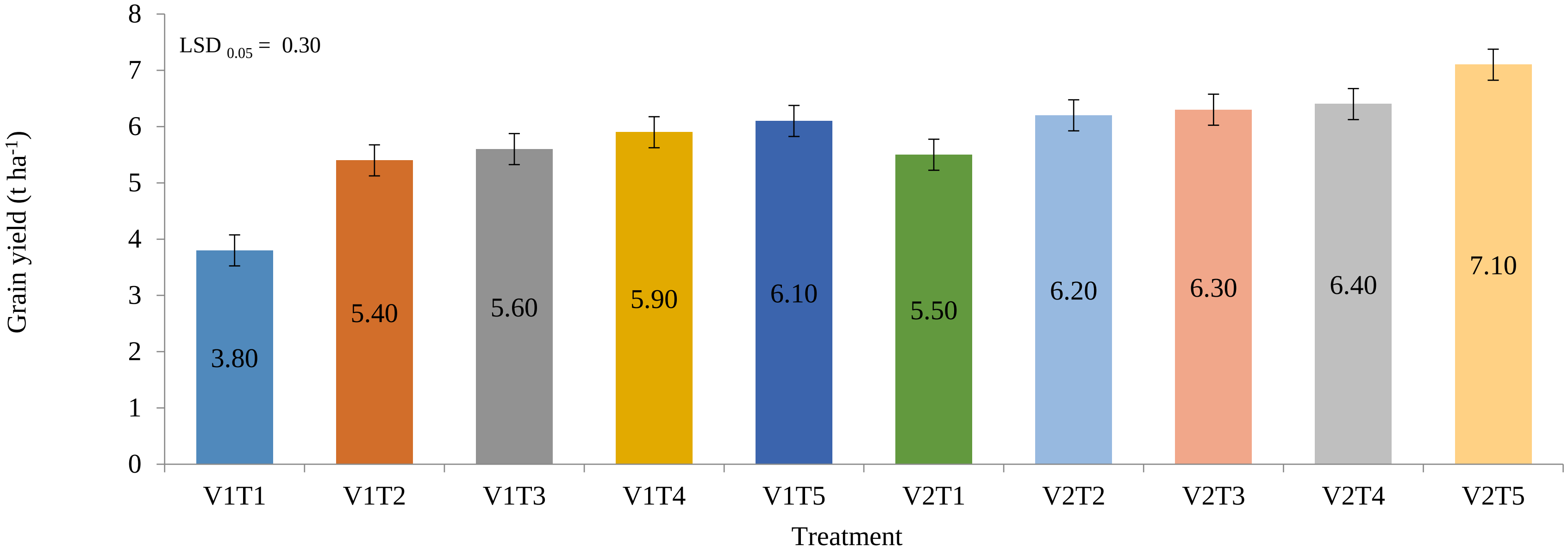


Figure 10. Interaction effect of variety and fertilizer treatments on grain yield

4.10 Straw yield (t/ha)

Straw yield significantly differed at different levels of nutrients supplied. These results are in alignment with Karmakar *et al.,* (2021) and Zhao *et al.* (2012). Among the varieties, V_2 produced the highest straw yield (8.42 t ha^{-1}) whereas the lowest straw yield was produced by V_1 (7.54 t) (Figure 7).

Straw yield per hectare was significantly affected by different types of fertilizer management treatments. Similar results were confirmed by Karmakar *et al.,* 2021; Artacho et al., 2009; Zhang et al., 2009; Haefele et al., 2008 who reported that nutrient rates strong significantly ($p<0.01$) influenced the grain yield might be due to disparity of the nutrient amount. Among the all fertilizer treatments, the highest straw yield observed in T_5 (8.8 t) and the lowest straw yield was in T_1 (7.2 t/ha) (Figure 8).

Interaction effect of varieties and fertilizer treatments on straw yield. These findings are similar to those of Karmakar *et al.,* 2021; Zhao *et al.*, 2012 and Fageria et al., 2010 who found that interactions of genotypes and nutrient rates significantly affected yield and yield components. Among the all treatment combinations, V_2T_5 produced the highest straw yield (9.3 t/ha) while the lowest straw yield (6.8t/ha) was in V_1T_1 (Figure 9).

From this research it was observed that variety BRRI dhan72 applied with 85 $kgha^{-1}$ N, 15 P $kgha^{-1}$, 55 $kgha^{-1}$ K, 12 S $kgha^{-1}$and 1.2 $kgha^{-1}$ Zn with 3.7 tha^{-1} poultry manure produced the maximum straw yield. On the other hand, BRRI dhan71 with no phosphorus fertilizer nor any poultry manure produced the minimum straw yield. Supply of nutrient with organic matter helps to higher productivity (Zaman *et al.* 2000); Reddy *et al.* (2005); Miah *et al.* (2004), and Umanah *et al.* (2003); Vanjau and Raju (2002); Channabasavanna (2003) and some other researcher also found the similar results.

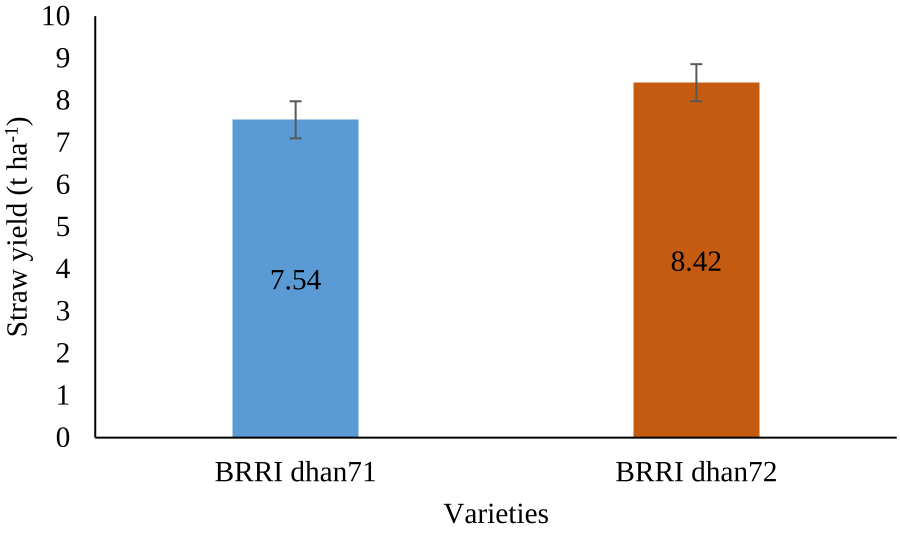


Figure 11. Straw yield of the tested rice varieties at different nutrient levels.

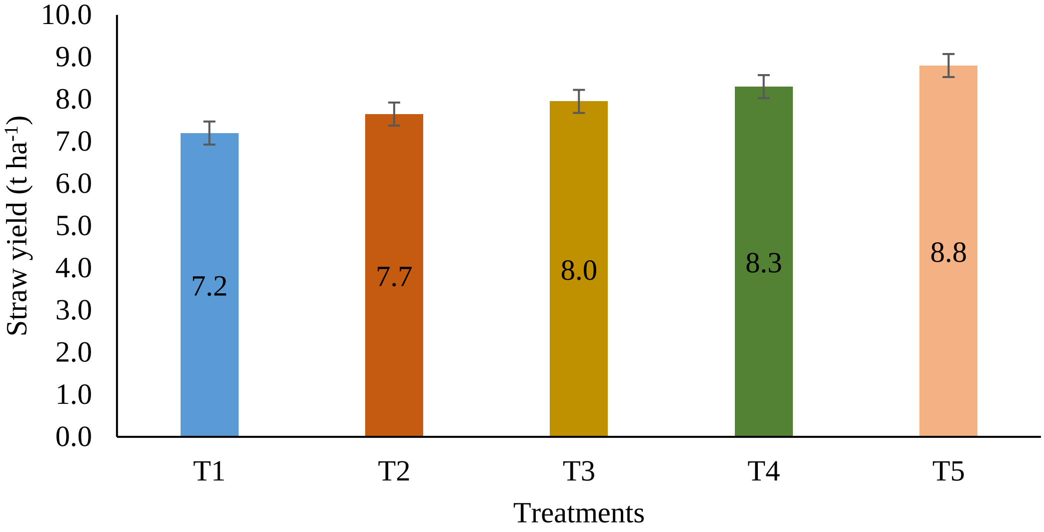


Figure 12. Effect of nutrient treatments on straw yield of the rice varieties

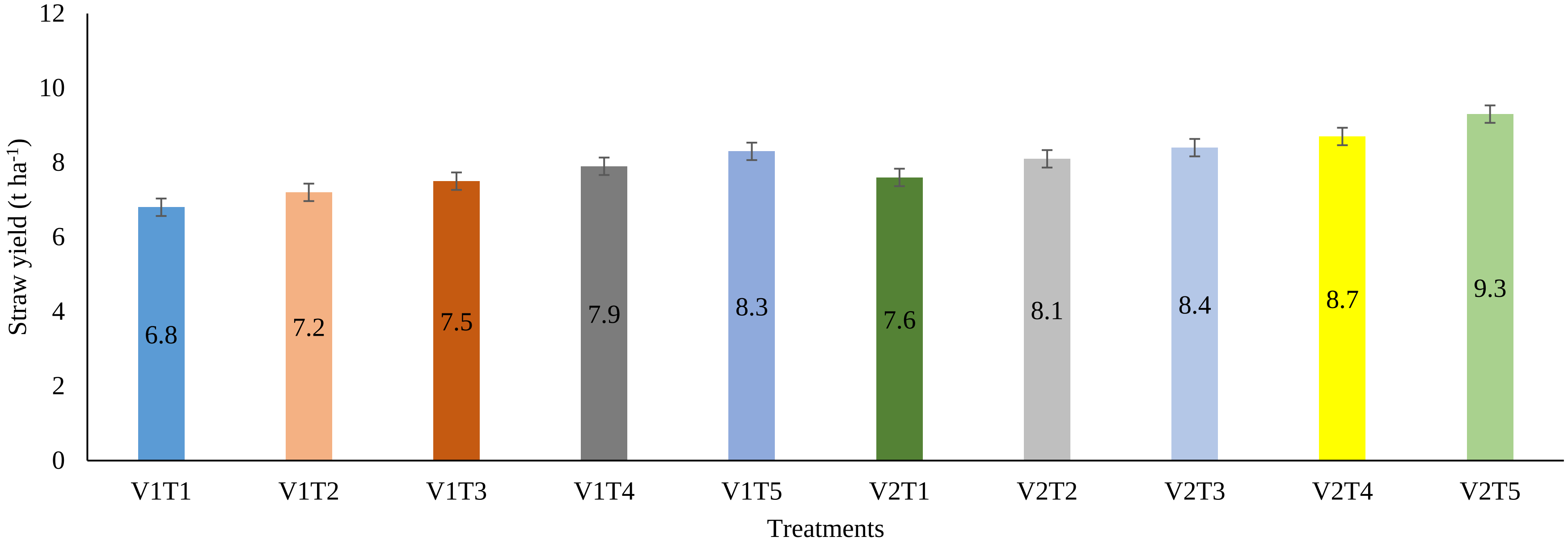


Figure 13. Interaction effect of variety and fertilizer treatments on straw yield

4.11 Harvest Index

Though there were no significant differences between the varieties in case of harvest index. Harvest index (42.8%) was higher for BRRI dhan72 variety and lower for variety BRRI dhan71 (41.6%).

Significant difference was also absent for effect treatments on harvest index. All the treatments but T_1 were statistically identical to each other whereas T_1 expressed lower percentage of harvest index.

Treatments interaction showed no significant effects on harvest index. All the treatments except V_1T_1 showed statistically identical harvest index whereas V_1T_1 showed lower harvest index. Harvest index mainly depends on genetic traits and environmental condition around the plants.

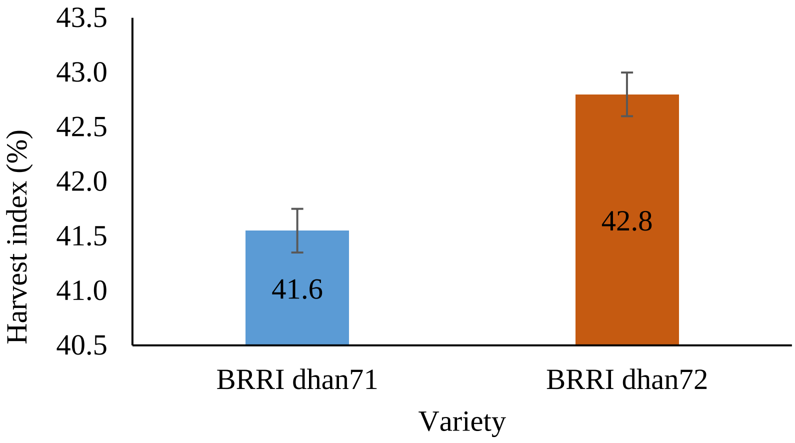


Figure 14. Harvest iIndex of the tested rice varieties at different nutrient levels.

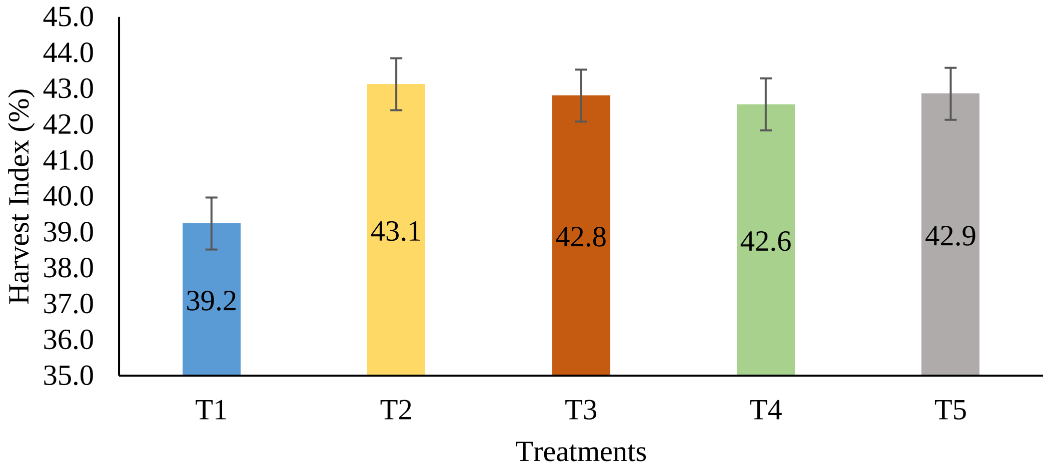


Figure 15. Effect of nutrient treatments on Harvest index of the rice varieties

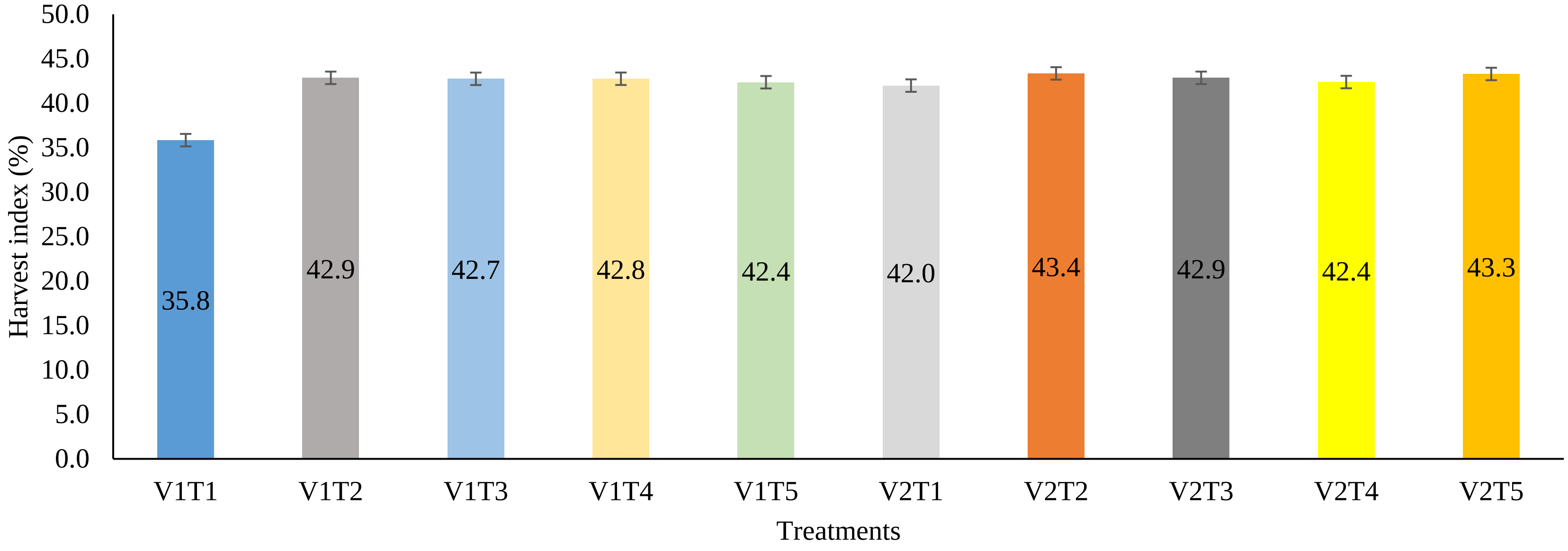


Figure 16. Interaction effect of variety and fertilizer treatments on harvest index

4.12 Post-Harvest soil properties

4.12.1 pH of Post-Harvest Soils

No significant variation was recorded in post-harvest soil pH due cultivation of different varieties (Table 9). Although there were no significant difference among the treatments, the highest pH of post-harvest soil (6.12) was found from V_1which BRRI dhan71. The lowest pH of post-harvest soil (6.02) was recorded from V_2. There were no significant variation recorded also in post-harvest soil pH due application of different fertilizer application (Table 10). Treatments combination also showed no significant variation in case of pH of postharvest soil. Highest pH was found in soil of V_1T_3 and V_1T_5 both was 6.2. And the lowest pH was recorded from V_2T_3 which was 5.9 (Table 11).

4.12.2 Organic matter of post-harvest soil

Table 6 is showing the effects of different varieties on organic matter status of post-harvest soils. It was found that organic matter status of post-harvest soil 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 (1.26%) was recorded from V_1 (Table 9).

It was found that organic matter status of post-harvest soil statistically differed due application of fertilizers. The maximum organic matter of post-harvest soil (1.38%) was found from T_5 which was statistically similar with T_4 (1.34%). The lowest organic matter of post-harvest soil (1.26%) was recorded from T_1 which was statistically similar with T_2 (1.30%) (Table 10).

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 (1.44%) was found from V_2T_5 which was statistically similar with V_2T_4 (1.38%). The lowest organic matter of post-harvest soil (1.20%) was recorded from V_1T_1 which was statistically similar with T_2 (1.20%) which was statistically similar with V_1T_2 (1.26%) and V_1T_3 (1.27%) (Table 11). Combination of organic and inorganic fertilizer improves soil organic matter content was also observed by Ilma *et al*. (2012); Golabi *et al*. (2007), Altieri *et al*. (2003).

4.12.3 Total N

Total N in post-harvest soil showed statistically significant differences due to the varieties (Table 6). The highest total N (0.057%) was found from V_2 while the lowest soil total N (0.052 %) was observed from V_1 treatment (Table 9).

It was found that total N status of post-harvest soil statistically differed due application of fertilizers. The maximum total N of post-harvest soil (0.069 %) was found from T_5 which was statistically identical with T_4 (0.066 %). The lowest total N content of post-harvest soil (0.041 %) was recorded from T_1 which was statistically identical with T_2 (0.042 %) (Table 10).

It was also found that total N status of post-harvest soil statistically differed due to different combinations of variety and fertilizers. The maximum total N content of post-harvest soil (0.069 %) was found from V_2T_5 which was statistically identical with V_1T_5 (0.068 %), V_2T_4 (0.066%) and V_1T_4 (0.065). The lowest total N content of post-harvest soil (0.032 %) was recorded from V_1T_1 (Table 11).

4.12.4 Available P

Available P in post-harvest soil showed statistically significant differences due to the varieties (Table 6). The highest available P (33.6ppm) was observed from V_2 treatment, whereas the lowest available P (30.8ppm) was found from V_1 treatment (Table 9).

Available P in post-harvest soil showed statistically significant differences due to the effect of different fertilizer treatments (Table 10). The highest available P (38.22 ppm) was observed from T_5 treatment, whereas the lowest available P (23.91 ppm) was found from T_1 treatment (Table 11). Ilma *et al.* (2012); Golabi *et al.* (2007), Altieri *et al.* (2003) also reported the similar type of result.

It was also found that available P status of post-harvest soil statistically differed due to different combinations of variety and fertilizers. The maximum available P content of post-harvest soil (38.74%) was found from V_2T_5 which was statistically identical with V_1T_5 (37.70 %) and statistically similar with V_2T_4 (36.50 %). The lowest available P content of post-harvest soil (18.41 %) was recorded from V_1T_1

4.12.5 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 (0.170 meq/100 g soil) was observed from T_5 treatment, which was statistically identical with T_4 (0.160 meq/100 g soil) and the lowest exchangeable K (0.125 meq/100 g soil) was recorded from T_1 treatment which was statistically similar (0.132 meq/100 g soil) to T_7 (Table 9).

Exchangeable K in post-harvest soil showed no statistically significant differences due to the varieties (Table 10).

It was also found that Exchangeable K status of post-harvest soil statistically differed due to different combinations of variety and fertilizers. The maximum Exchangeable K content of post-harvest soil (0.170 meq/100 g soil) was found from V_2T_5 which was statistically similar with V_2T_4 (0.160 meq/100 g soil). The lowest Exchangeable K content of post-harvest soil (0.125 meq/100 g soil) was recorded from V_1T_1 which was statistically similar with V_1T_2 (0.132 meq/100 g soil) (Table 11). It was supported by the studies by Ilma *et al*. (2012); Golabi *et al*. (2007), Altieri *et al*. (2003).

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Table 9: Effects of Variety on different attributes of post-harvest soil

Varieties	pH	Organic matter content (%)	Total N content (%)	Available p content (ppm)	Exchangeable K content (meq)
V_1	6.12	1.26	0.052 b	30.8 b	0.145
V_2	6.02	**1.37**	**0.057 a**	**33.6 a**	0.145
LSD $_{(0.05)}$	N/S	**N/S**	0.003	1.05	N/S
C. V. (%)	7.86	3.24	4.56	4.98	4.53

Note# V_1: BRRI dhan71, V_2: BRRI dhan72

Table 10: Effects of fertilizer treatments on different attributes of post-harvest soil

Treatments	pH	Organic matter content (%)	Total N content (%)	Available p content (ppm)	Exchangeable K content (meq)
T_1	6.0	**1.26**	**0.042 c**	**23.91 e**	**0.125 c**
T_2	6.1	**1.30**	**0.041 c**	29.95 d	**0.132 bc**
T_3	6.0	1.31	0.056 b	33.18 c	0.139 b
T_4	6.1	**1.34**	**0.066 a**	35.92 b	**0.160 a**
T_5	6.1	**1.38**	**0.069 a**	**38.22 a**	**0.170 a**
LSD $_{(0.05)}$	N/S	N/S	0.09	0.05	0.21
C. V. (%)	7.52	2.77	6.69	4.25	6.30

Note# T_1: N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$, T_2: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$, T_3: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$, T_4: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha, T_5: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha

Table 11: Combined effects of Varity and fertilizer treatments on different attributes of post-harvest soil

Treatments	**pH**	**Organic matter content (%)**	**Total N content (%)**	**Available p content (ppm)**	**Exchangeable K content (meq)**
V_1T_1	6.0	**1.20**	0.032 d	18.41 e	0.121 d
V_1T_2	6.2	**1.24**	0.041 c	29.57 d	0.133 cd
V_1T_3	6.1	**1.25**	0.053 b	33.12 c	0.145 bc
V_1T_4	6.1	1.30	**0.065 a**	35.34 bc	0.159 ab
V_1T_5	6.2	1.32	**0.068 a**	**37.70 a**	**0.167 a**
V_2T_1	6.1	1.33	0.053 b	29.41 d	0.128 d
V_2T_2	6.0	1.36	0.041 c	30.32 d	0.131 cd
V_2T_3	5.9	1.37	0.058 b	33.23 c	0.132 cd
V_2T_4	6.1	**1.38**	**0.066 a**	**36.50 ab**	**0.161 a**
V_2T_5	6.0	**1.44**	**0.069 a**	**38.74 a**	**0.172 a**
LSD $_{(0.05)}$	N/S	N/S	0.006	2.35	0.016
C. V. (%)	7.52	2.77	6.69	4.25	6.30

Note# V_1: BRRI dhan71; V_2: BRRI dhan72; T_1: N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$; T_2: N_{85} $K_{55}S$ $_{12}Zn_{1.5}$; T_3: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$; T_4: N_{85} $P_{15(\text{from TSP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha; T_5: N_{85} $P_{15(\text{from DAP})}$ $K_{55}S$ $_{12}Zn_{1.5}$ +Poultry manure 3.7 t/ha

CHAPTER V

SUMMERY AND CONCLUSION

Rice is needed a high amount of fertilization for better production. Mentionable amount of nutrient is lost from the soil in various ways like runoff, fxation, leaching, and volatilization. Reduction of organic matter is also a major constrain to the productivity of soil in Bangladesh. So it's necessary to adopt some new technique 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 June 2019 to December 2019, with a view to observe the effects of organic and inorganic phosphorus on the performance of modern T. aman rice (*Oryza sativa* L.) showed differences in terms of different characters at Aman season under the Modhupur Tract (AEZ-28).

There were altogether two varieties viz: V_1= BRRI dhan71 and V_2= BRRI dhan72 and five fertilizer treatments viz: T_1= N_{85} P_0 K_{55} $S_{12}Zn_{1.5}$, T_2= T_1+ P_{15} T_3= T_1 +$P_{15\text{ (from DAP)}}$, T_4= T_1+$P_{15\text{(from TSP)}}$ + Poultry manure 3.7 t ha^{-1}, T_5= T_1+ $P_{15\text{ (from DAP)}}$+ Poultry manure 3.7 t ha^{-1}. In total ten treatment combinations consisting of varieties and different source of phosphorus.

BRRI dhan72 produced taller plant (111.0 cm) compared to BRRI dhan71 (101.5 cm). Plant height increased with increasing nutrient rates and combination of organic and inorganic fertilizers.

BRRI dhan72 produced higher number of tillers and panicle per hill (21.2 and 17.2) compared to BRRI dhan71 (17.1 and 12.8). No. of tillers and panicle increased with increasing nutrient rates and combination of organic and inorganic fertilizers.

It was observed that BRRI dhan72 (28.6 cm) produced the longer panicle and BRRI dhan71 (23.8 cm) produced the shorter panicle. Among the treatments T_5

(29.6 cm) produced the longest panicle and treatment T_1 (23.0 cm) produced the shortest panicle. Combination V_2T_5 (33.8 cm) produced the longest panicle. On the other hand treatment T_1 (20.1 cm) produced the shortest.

BRRI dhan72 also produced higher number of filled, unfilled and total no. of spikelets per hill (111.3, 76.6 and 34.7 respectively). On the other hand BRRI produced the lower no. of filled, unfilled and total no. of spikelets per hill (29.6, 117.9 and 88.9 respectively). Among the combinations V_2T_5 produced maximum total number of grains per panicle, filled grains and unfilled grains (123.6, 96.5 and 27.1respectively) and V_1T_1 produced minimum (106.9, 69.1 and 37.8 respectively).

In general, grain weight of BRRI dhan72 was higher than BRRI dhan71 in case all the treatments and interactions of variety and nutrients rates. Among the treatments T_5 (26.4 g) produced the maximum weight of 1000-grain and treatment T_1 (23.9 g) produced the minimum. Among the combinations V_2T_5 (27.9 g) produced the maximum weight of 1000-grain and treatment V_1T_1 (23.1 g) produced the minimum Weight of 1000-gram grain.

Among the varieties, BRRI dhan72 produced the highest grain yield (6.30 t ha^{-1}) while the lowest grain yield (5.36 t ha^{-1}) was produced by BRRI dhan71. The treatments, T_5 produced the highest grain yield (6.60 t ha^{-1}) while the lowest grain yield (4.65 t)was produced by T_1 Among the all treatment combinations, V_2T_4 produced the highest grain yield (7.10 t ha^{-1}) and the lowest grain yield (3.80 t ha^{-1}) was in V_1T_1.
highest straw yield (8.42 t ha^{-1}) was produced by BRRI dhan72 while the lowest straw yield (7.54 t ha^{-1}) was produced by BRRI dhan71. The treatments, T_5 produced the highest straw yield (8.8 t ha^{-1}) while the lowest straw yield (7.2 t)was produced by T_1 Among the all treatment combinations, V_2T_5produced the highest straw yield (9.3 t ha^{-1}) and the lowest straw yield (6.8 t ha^{-1}) was in V_1T_1. In case of harvest index there were no significant variation found. All the varieties and treatments showed similar result except T_1.

CONCLUSION

Regarding as the above results, it could be concluded that BRRI dhan72) performed the better compared to BRRI dhan71. . Among the treatments, T_5 (N_{85} $P_{15\ (\text{from DAP})}$ K_{55} S_{12} $Zn_{1.5}$ +Poultry manure 3.7 tha^{-1}) was the best for both the varieties BRRI dhan71 and BRRI dhan72 in respect of yield and yield components. Moreover, in combination of BRRI dhan72 and T_5 performed the best in case of most of the vegetative and yield characteristics like Plant height, Panicle length, total number of tiller, Effective tiller, Number of filled and Unfilled grain, 1000 grain weight, fresh and dry weight of grain and straw and grain yield. Therefore, BRRI dhan72 with the treatmentT_5 (N_{85} $P_{15\ (\text{from DAP})}$ K_{55} S_{12} $Zn_{1.5}$ + Poultry manure 3.7 tha^{-1}) would be recommended to attain best performance and sustainable cultivation of T. Aman rice.

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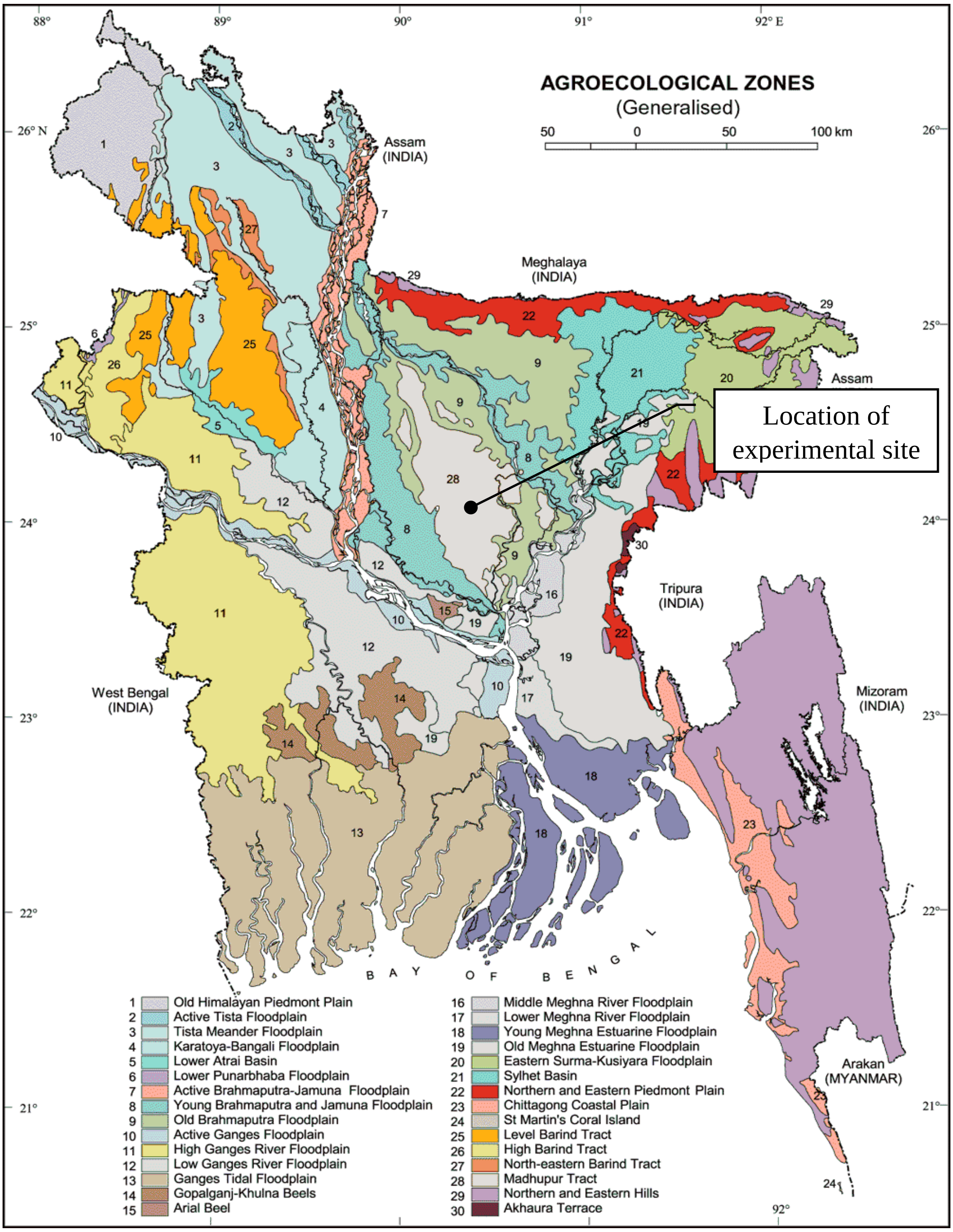
APPENDICES

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

Source: (FAO and UNDP, 1988)

Appendix III: Physical and chemical properties of the soil

Characteristics	Value
Particle size analysis	
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
Consistency	Granular and friable when dry
pH	5.6
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.53
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.06
Available P (ppm)	20.0
Exchangeable K (meq/100g soil)	0.12

Source: SRDI, 2015

Appendix IV: Image showing sowing of seedling

Appendix V: Image showing overview of field

Appendix VI: Image showing field with mature grain

Appendix VII: Image showing overview of field