# EFFECT OF PHOSPHORUS AND SULPHUR ON THE GROWTH AND YIELD OF BRRI dhan56

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# CERTIFICATE

This is to certify that the thesis titled, **"Effect of phosphorus and sulphur on the growth and yield of BRRI dhan56"** submitted to the **Department of Soil Science Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka** in partial fulfillment of the requirements for the degree of **Master Of Science (M.S.) in Soil Science** embodies the result of a piece of bona fide research work carried out by Md. Homayune Kabir; **Registration No. 06-02056** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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## ABSTRACT

An experiment was conducted at the Research Field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, during the period from July, 2013 to December, 2013 to study the performance of BRRI dhan56 regarding to growth, yield and yield contributing characters under the AEZ-28. The two factors experiment consists with four levels of phosphorus (P) *viz.* $P_0$: without phosphorus (control), $P_1$: 20 kg $ha^{-1}$, $P_2$: 40 kg $ha^{-1}$ and $P_3$: 60 kg $ha^{-1}$ and four levels of sulphur *viz.* $S_0$: without sulphur (control), $S_1$: 10 kg $ha^{-1}$, $S_2$: 20 kg $ha^{-1}$ and $S_3$: 30 kg $ha^{-1}$. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. It was found that all the traits were statistically significant due to phosphorus whereas the tallest plant (109.70 cm) and maximum tillers $hill^{-1}$ (15.99) was found in treatment $P_2$ (40 kg P $ha^{-1}$) at harvest. Treatment $P_2$ (40 kg P $ha^{-1}$) also recorded the maximum results on effective tillers $hill^{-1}$ (13.67), filled grains $panicle^{-1}$ (138.60), 1000-grain weight (26.73 g), grain, straw and biological yield (5.12, 8.39 and 13.51 t $ha^{-1}$, respectively) and harvest index (37.85%) at harvest while $P_0$ (control) obtained the minimum results on the above traits (7.98, 110.0, 22.83 g, 3.77 t $ha^{-1}$, 7.05 t $ha^{-1}$, 10.82 t $ha^{-1}$ and 34.82%, respectively). In case of sulphur, all the traits were significant except plant height at 55DAT and filled grains $panicle^{-1}$ whereas 20 kg S $ha^{-1}$ obtained the tallest plant (109.40 cm) at harvest and maximum tillers $hill^{-1}$ (14..75) at harvest. The maximum effective tillers $hill^{-1}$ (12.12), 1000-grain weight (27.52 g), grain, straw and biological yield (4.75, 8.08 and 12.83 t $ha^{-1}$, respectively) and harvest index (36.90%) were observed in $S_2$ (20 kg S $ha^{-1}$) at harvest. All the studied characters were also significantly different by the interaction effect between phosphorus and sulphur fertilizers whereas interactions effect of $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) perform better than that of other interactions. The interaction effect of $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) produced maximum effective (15.53) and minimum non effective tillers $hill^{-1}$ (1.97), maximum filled (141.40) and minimum unfilled grains $panicle^{-1}$ (7.87), highest 1000-grain weight (30.75 g), highest yield of grain, straw and biological (5.64, 8.97 and 14.61 t $ha^{-1}$) and higher HI (38.59%). So, the present findings obviously recommended that 40 kg P $ha^{-1}$ or 20 kg S $ha^{-1}$ singly or their interactions would be optimum level for getting the higher production of BRRI dhan56.

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# ABBREVIATIONS

| | | |
|---|---|---|
| % | = | Percentage |
| µM | = | Micro mol |
| $^0$C | = | Degree Celcius |
| AEZ | = | Agro–Ecological Zone |
| Agric. | = | Agriculture |
| Agril. | = | Agricultural |
| ANOVA | = | Analysis of variance |
| B | = | Boron |
| BARC | = | Bangladesh Agricultural Researcher Council |
| BARI | = | Bangladesh Agricultural Research Institute |
| BAU | = | Bangladesh Agricultural University |
| BBS | = | Bangladesh Bureau of Statistics |
| BRRI | = | Bangladesh Rice Research Institute |
| CRD | = | Completely randomized design |
| cv. | = | Cultivar |
| DAS | = | Days after sowing |
| DAT | = | Days after transplanting |
| DMRT | = | Duncan's Multiple Range Test |
| e.g. | = | Exempli gratia (by way of example) |
| EFSB | = | eggplant fruit and shoot borer |
| *et al.* | = | And others |
| FA | = | Foliar application |
| FAO | = | Food and Agriculture Organization |
| g | = | Gram |
| i.e. | = | edest (means That is ) |
| IRRI | = | International Rice Research Institute |
| K | = | Potassium |
| LSD | = | Least significant difference |
| $mgL^{-1}$ | = | Milligram per litre |
| P | = | Phosphorus |
| pH | = | Negative logarithm of hydrogen ion |
| RCBD | = | Randomized Complete Block Design |
| SA | = | Soil application |
| spp | = | Species (plural number) |
| UAE | = | United Arab Emirates |
| USDA | = | United stage of developmental agriculture |
| var. | = | Variety |
| Viz. | = | Namely |
| Zn | = | Zinc |

# CHAPTER I

# INTRODUCTION

Agriculture is the single largest producing sector of economy since it comprises about 21% of the GDP of Bangladesh and employing around 60% of the total labor force. Intensive rice cultivation is the most dominated agricultural practices in Bangladesh. Rice contributes 87.29% of the total grain production and covers 61% of the total calorie intake of the people of the country (MoA, 2009). Geographical and agro-climatic conditions of Bangladesh are favorable for rice cultivation. Bangladesh is the 5$^{th}$ largest country of the world in respect to rice cultivation (BBS, 2012) where about 80% of the total cultivable land is used for rice production. Aus, aman and boro comprise about 7%, 47% and 46% of the total rice production of this country (BBS, 2010).

In Bangladesh, agriculture is dominated by intensive rice (*Oryza sativa* L.) cultivation. Globally, rice is the second most important cereal crop to wheat in terms of area but as food it is the most important since it provides more calorie than any other cereals. Rice is the single most important human energy source. It is the staple food for a majority of the population including 560 million hungry people in Asia (Mohanty, 2013). In Bangladesh, rice ranks first in terms of both area and production. Rice is not only the foremost staple food, it also provides nearly 40% of total national employment (48% of total rural employment), about two-thirds of total calorie supply and about half of the total protein intake of an average person in the country (Bhuiyan and Karim, 1999).

Soil is the store house of plant nutrients. Plant derives 16 essential nutrients from the soil. But soil vary considerably in their inherent capacities to supply nutrients which is gradually declining over times due to intensive cropping with high yielding varieties, very little or no use of organic materials and improper soil and crop management practices.

Fertilizers are indispensable for the crop production systems of modern agriculture. Among the factors affecting crop production, fertilizer is the single most important factor that plays a crucial role in yield increase, provided other factors are not too limiting. That is why chemical fertilizer today holds the key to the success of the crop production systems of Bangladesh agriculture, being responsible for about 50% of the reduction (BARC, 2012).

Among the plant nutrients, phosphorus fertilizer is a major essential plant nutrient and key input for increasing crop yield (Dastan *et al*, 2012 and Alinajati Sisie & Mirshekari, 2011) and nutrient concentration of rice (Hossain *et al*., 2009 and Fang *et al*., 2008). It palys a vital role in several physiological processes *viz* photosynthesis, respiration, energy storage and cell division/enlargement. It is also an important structural component of many biochemicals *viz* nucleic acid (DNA, RNA enzymes and co-enzymes) and also stimulates root growth and associated with early maturity of crops (Yosef, 2013a and b). It is also important for the phosphorus accumulation in cultivated soils is a concern for non-point environmental pollution and for efficiency of phosphorus resources because of excessive phosphorus input (Li *et al*., 2010). Phosphorus deficit is a most important restrictive factor in plant growth and recognition of mechanisms that increase plant phosphorus use efficiency is important (Alinajoati Sisie & Mirshekari, 2011). So, the appropriate fertilizer input that is not only for getting high grain yield but also for attaining maximum profitability (Khuang *et al*, 2008). It stimulates early root growth and development, encourages more active tillering and promotes early flowering, maturity and good grain development (Khandaker, 2003). Manzoor *et al*., (2006) reported that the different varieties may have varying responses to P fertilizers depending on their agronomic traits. The application of phosphorous fertilizer either in excess or less than optimum rate affects both yield and quality to a remarkable extent. Similarly, P is a major component in ATP, the molecule that provides ”energy” to that plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material DNA and RNA.

Phosphorus application to rice increased P accumulation but did not consistently increase rice yields because flooding decreased soil P sorption and increased P diffusion.

Sulphur (S) is another essential macronutrient and it plays a vital role in the plant system and its deficiency in Bangladesh was first detected in rice at BRRI farm at Joydebpur in 1976. In recent years, S deficiency has been receiving much attention as a major limiting factor for wetland rice. For rice cultivation, next to nitrogen, S application is very important. So, in fertilizer schedule, it is commonly included (Islam *et al.*, 2009). Sulphur deficiency affects not only the growth and yield of rice but also the protein quality through its effect on the synthesis of certain amino acids such as cystein and methionine. The use of almost sulphur free fertilizer such as urea and triple super phosphate (TSP) may be an important reason for widespread occurrence of sulphur deficiency problem.

Continuous application of chemical fertilizers accelerates the depletion of soil organic matter and impairs physical and chemical properties of soil in addition to micronutrient deficiencies. Now it is true that use of fertilizers stands as a major factor for environmental pollution. Large scale use of chemical fertilizers has created a potential health hazard, has reduced microbial population and earthworm activities, affecting soil health and has reduced utility of water bodies for men, animals and fishes (Bhuiyan *et al.,* 1999). In addition, chemical fertilizers are always expensive inputs for crop production, especially in a developing country like Bangladesh.

Global environmental pollution can be reduced by application of reduced rates of fertilizers. Moreover, chemical fertilizers are likely to be even more costly in near future. The actual recommended rates of P and S not only maintain soil health for sustainable agriculture but also save part of the cost of crop production.

Considering the above points, the present study was undertaken with the following objectives:

- to investigate the differences of growth characteristics and grain production of BRRI dhan56 as influenced by P and S
- to find out the appropriate doses of P and S regarding to proper growth and higher production of BRRI dhan56
- to select the most advantageous treatment combination of P and S fertilizers concerning to growth and yield of BRRI dhan56.

# CHAPTER II

# REVIEW OF LITERATURE

This chapter contains a brief and relevant review of many researchers in relation to the effects of P and S on the growth and yield of BRRI dhan56 in Bangladesh perspective and also in the other parts of the world. The related review of literature was present under the following heading and sub headings:

## 2.1 Effect of phosphorus (P) on growth and yield characters 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 (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$^{-1}$.

Yosef (2013a) investigated the effect of nitrogen and phosphorus fertilizer on growth and yield in rice cultivar Tarom Hashemi, where Nitrogen fertilizer at 50,100 and 150 kg ha$^{–1}$ was main plot and phosphorus fertilizer 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) 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 $P_1$ to $P_4$ 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.

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.

Yosef (2012) studied to investigate the effect of nitrogen and phosphorus fertilizer on growth and yield in rice cultivar Tarom Hashemi, an experimental design in north of Iran in 2011 cropping season. Nitrogen fertilizer at 50,100 and 150 kg ha$^{-1}$ was main plot and phosphorus fertilizer at 4 level 0 (control), 30, 60 and 90 kg ha$^{-1}$ as sub plot. Using randomized complete block design (RCBD) with 3 replications. The results showed that tiller number, fertile tiller, total grain, 1000-grain weight and yield increased significantly with nitrogen and phosphorus fertilizer. Interesting in comparison to 50 and 100 kg ha$^{-1}$ level application of higher N-fertilizer 150 kg ha$^{-1}$ showed a positive respond to application of high nitrogen for Taroom Hashemi cultivar. Effect of different application of P-fertilizer was significantly on this parameter, increase application of phosphorus increase parameter above. Study of interaction effect of N and P- fertilizer was significant in fertile tiller and 1000-grain weight.

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$^{-1}$.

Tang *et al.* (2011) performed a field experiments on winter wheat (Triticum aestivum L.)–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 dhan 36, BRRI dhan 45, 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 t/ha 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 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 *et al*. (2008) perfoemed 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 returns were calculated based on crop price and input costs. At the 25-lb-acre P2O5 rate the polymer coated treatments produced greater yields than equivalent non coated treatments. At higher P2O5 rates both polymer coated and non coated treatments produced equivalent yields. The 25-lb P2O5 coated TSP treatment produced the greatest returns to producers.

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 $ha^{-1}$.

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 $H_2O$. 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.

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 (6 t $ha^{-1}$), green manure (10 t $ha^{-1}$) and Iron Pyrites (10% by weight). The results showed that high grade phosphate rock (M, 34/74) with organic manure performs well and were followed by PR (34/74) with iron pyrites and green manure. Thus, PR (34/74) performs well with organic matter, $FeS_2$ 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.

Dongarwar *et al.* (2003) conducted an experiment in Bhandara, Maharashtra, India during kharif 2000-2001 to investigate the requirement of phosphorus for rice (KJTRH-1) production. They observed there was a significant increase in grain yield with successive increase in P fertilizer. The highest grain yield (53.05 q ha-1) was obtained with 75 kg P $ha^{-1}$.

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$^{-1}$).

**2.2 Effect of sulphur (S) on growth and yield characters of rice**

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

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

($T_8$) in alkali soils respectively. The highest grain (4678 kg $ha^{-1}$) and straw yields (5642 kg $ha^{-1}$) was noticed with application of 20 kg S + 10 kg Zn $ha^{-1}$ in alkali soils.

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

Singh *et al.* (2012) conducted a field experiment to evolve suitable nutrient management system with respect to one secondary nutrient (sulphur) and one micro nutrient (zinc) in rice for Indo- Gangetic plains of Bihar at ICAR Research Complex for Eastern Region Patna during 2008-09. Total 16 treatment combination was tested i.e. four level of sulphur $S_1$ (0 kg), $S_2$ (20 kg), $S_3$ (30 kg), and $S_4$ (40 kg) and zinc $Zn_1$ (0 kg), $Zn_2$ (4 kg), $Zn_3$ (5 kg) and $Zn_4$ (6 kg) were applied in combination, respectively, was applied on hectare basis. Application of sulphur at 20 kg $ha^{-1}$ produced significantly taller plants over no application of sulphur ($S_1$) at all the growth stages. Plots received 20 kg sulphur produces significantly higher LAI over no application and produced at par with other tested levels of sulphur in most of the phenological stages. Yield attributes were also influenced significantly with graded doses of sulphur. In case of sulphur, application at 20 kg $ha^{-1}$ produced rice grain 7.25 t $ha^{-1}$ significantly over control ($S_1$) however it produced significantly lower than other tested levels of i.e. $S_3$ (7.44 t $ha^{-1}$) and $S_4$ (7.51 t $ha^{-1}$). Harvest index (HI) was not influenced significantly by any of tested factor.

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

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

Jawahar and Vaiyapuri (2010) carried out a field experiment at Experimental Farm, Annamalai University, Annamalai Nagar, Tamil Nadu, India during 2007-2008 to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. Among the different levels of sulphur, application of 45 kg S ha$^{–1}$ recorded maximum grain and straw yield of rice, which was closely followed by 30 kg S ha$^{–1}$. This treatment recorded 18.12, 7.47 and 2.43 per cent increase over 0, 15 and 30 kg S ha$^{–1}$. Higher grain and straw yield due to S may be attributed to increase in growth and yield characters of rice and to be stimulating effect of applied S in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency, which in turn increased the yield.

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

Rahman *et al*. (2009) studied the effect of different levels of Sulphur on growth and yield of BRRI dhan41 at Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh during T. aman season of 2007. The treatments used in the experiment were $T_0$ (without S), $T_1$ (50% RFD of S), $T_2$ (75% RED of S), $T_3$ (100% RFD of S), $T_4$ (125% RFD of S), $T_5$ (150% RFD of S), $T_6$ (175% RFD of S) and $T_7$ (200% RFD of S). All yield contributing characters like effective tillers hill$^{-1}$ filled grain panicle$^{-1}$, grain yield, straw yield, biological yield and 1000-grain weight except plant height and panicle length of BRRI dhan41 significantly responded to different levels of applied S.

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

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

Lar Oo *et al*. (2007) studied on the effect of N and S levels on productivity and nutrient uptake in aromatic rice. Growth and yield attributes, grain, straw and biological yields increased significantly with N and S levels. The increase in grain yield due to application of 100 and 150 kg N $ha^{-1}$ over control was 1.99 tonnes $ha^{-1}$ and 1.95 tonnes and in terms of percentage increase was 49.5 and 48.5% respectively. The percentages increase in the grain yield of rice at application of 20, 40 and 60 kg S $ha^{-1}$ over the control were in the order of 6.5, 7.3 and 8.8% respectively.

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

Biswas *et al.* (2004) reported the effect of S in various region of India. The optimum S rate varied between 30-45 kg $ha^{-1}$. Rice yields increased from 5 to 51%. Across the crops and regions the agronomic efficiency varied from 2 to 27%.

Peng *et al.* (2002) conducted a field experiment where one hundred and sixteen soil samples were collected from cultivated soils in Southeast Fujian, China. Field experiments showed that there was a different yield increasing efficiency with application S at the doses of 20-60 kg $ha^{-1}$ to rice plant. The increasing rate of rice yield was 2.9-15.5% over control. A residual effect was also observed.

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

Raju and Reddy (2001) studied the response of both hybrid and conventional rice to Sulphur (at 20 kg $ha^{-1}$) and Zinc (at 10 kg $ha^{-1}$) applications. Conventional rice, MTU 2067 out yielded the hybrid rice MUT-HR 2003 by 21%. Significant improvement in grain yield was observed due to sulphur application. Zinc application failed to improve the yield markedly.

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

Poongothai *et al.* (1999) showed that application of 60 kg S $ha^{-1}$ as gypsum along with green leaf manure at the rate of 6.25 t $ha^{-1}$ increased the Sulphur use efficiency, straw and grain yields of rice

Sarkunan *et al.* (1998) carried out a pot experiment to find out the effect of P and S on the yield of rice under flooded condition on a P and S deficient sandy loam soil. Increasing levels of P from 0-100 mg $kg^{-1}$ progressively increased the grain yield from 16.9 to 42.5 g $pot^{-1}$. Sulphur addition at 25 mg $kg^{-1}$

resulted in 9% increase in grain yield. The treatment combination of 100 mg P and 10 mg S $kg^{-1}$ soil gave significantly higher grain yield than the other treatments.

Mandal and Halder (1998) conducted a pot experiment using rice cv. BR11 with all combinations of 0, 4, 8 or 12 kg Zn $ha^{-1}$ and 0, 5, or 20 kg S $ha^{-1}$. Addition of 8 kg Zn+ 20 kg S $ha^{-1}$ gave the best performance in growth and yield of rice.

Uddin *et al.* (1997) conducted a field experiment in Patuakali during aman season of 1990 to see the effect of N, P, and S on the yield of rice cv. Haloi. They reported that application of 20 kg S $ha^{-1}$ increased tillering, grains $panicle^{-1}$ and grain yield of rice.

Sahu and Nandu (1997) carried out two field experiments, one in black soil and other in laterite soil to determine the response of rice cv. Jajati and Lalat to sulphur (0-60 kg $ha^{-1}$) in Orissa. They observed that mean grain yield increased with up to 40 kg S $ha^{-1}$ on black soil and the yield was the highest with 60 kg S $ha^{-1}$ on the laterite soil.

Gupta *et al.* (1997) conducted field experiments in the karif seasons of 1996 and 1997 at one Regional Agricultural Research Station, India to study the effects of sulphur sources sulphur powder, gypsum, iron pyrites and sulphur dose (0, 10, 20, 30 or 40 kg S $ha^{-1}$) on rice. They showed that compared with controls, rice grain yield increased by 14.2, 24.2, 25.6 and 20.1% with the four rates of sulphur respectively. The optimum dose was 20 kg S $ha^{-1}$.

Islam *et al.* (1996) conducted field experiments during T. aman season of 1992 to examine the response of BR11 rice to S, Zn and B. They found that application of 20 kg S $ha^{-1}$ at both locations significantly increased the grain yield of rice.

Tandon *et al*. (1995) observed that S application of 20 to 60 kg $ha^{-1}$ significantly increased grain yield of rice and the average yield response due to

S application was 17.1%. He also noted different sources of S were equally effective.

Islam *et al*. (1995) carried out a field experiment during aman season of 1992 to investigate the response of BR31 rice to different nutrients including S. They reported that application of 20 kg S $ha^{-1}$ with 100 kg N $ha^{-1}$ increased the grain yield by 1300 kg N $ha^{-1}$ application.

# CHAPTER III

# MATERIALS AND METHODS

This chapter contains a brief description of experimental site, soil, climate, crops, treatments, experimental design, land preparation, transplanting of seedling, intercultural operations, harvesting, data recording, collection and preparation of soil and plant samples and the methods for the physical and chemical and statistical analysis. The details of the materials and methods are presented below.

## 3.1 Site Description

### 3.1.1 Geographical Location

Geographically, the experimental area is located at $23^0 41'$ N latitude and $90^0 22'$ E longitudes. The area lies at 8.6 meter above mean sea level (Anon., 2004b).

### 3.1.2 Agro–Ecological Region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988b).

### 3.1.3 Soil

The soil of the experimental site belongs to the general soil type, Deep Red Brown Terrace Soils under Tejgaon Series. Top soils were silty loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.8 and had organic matter 1.3%. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. Soil samples were analyzed for both physical and chemical properties in the laboratory of the SRDI, Farmgate, Dhaka. The properties studied included pH, organic matter, total N, available P and exchangeable K. The soil was analyzed following standard methods. Particle-size analysis of soil was done by Hydrometer method and soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5. The physico-chemical properties of the soil are presented in Appendix I.

### 3.1.4 Climate and weather

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature recorded by the National Meteorological Research Centre, Dhaka during the period of study have been presented in Appendix II.

## 3.2 Details of the Experiment

### 3.2.1 Plant materials (variety)

The seeds of BRRI dhan56 were used as planting materials which was collected from the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur–1701.

### 3.2.2 Experimental treatments

Different doses of phosphorus (P) and sulphur (S) were applied in the experimental field as experimental treatments where P and S were used as factor A and B, respectively. From the above experimental treatments it will be mentioned as are as follows

**Factor A:** Four doses of phosphorous (P)

$P_0$ : 0 kg P ha$^{-1}$ (control)
$P_1$ : 20 kg P ha$^{-1}$
$P_2$ : 40 kg P ha$^{-1}$
$P_3$ : 60 kg P ha$^{-1}$

**Factor B:** Four doses of sulphur (S)

$S_0$ : 0 kg S ha$^{-1}$ (control)
$S_1$ : 10 kg S ha$^{-1}$
$S_2$ : 20 kg S ha$^{-1}$
$S_3$ : 30 kg S ha$^{-1}$

So, the treatments combinations were as follows

$P_0S_0$ : 0 kg P ha$^{-1}$ × 0 kg S ha$^{-1}$ (control)
$P_0S_1$ : 0 kg P ha$^{-1}$ × 10 kg S ha$^{-1}$
$P_0S_2$ : 0 kg P ha$^{-1}$ × 20 kg S ha$^{-1}$
$P_0S_3$ : 0 kg P ha$^{-1}$ × 30 kg S ha$^{-1}$
$P_1S_0$ : 20 kg P ha$^{-1}$ × 0 kg S ha$^{-1}$
$P_1S_1$ : 20 kg P ha$^{-1}$ × 10 kg S ha$^{-1}$
$P_1S_2$ : 20 kg P ha$^{-1}$ × 20 kg S ha$^{-1}$
$P_1S_3$ : 20 kg P ha$^{-1}$ × 30 kg S ha$^{-1}$
$P_2S_0$ : 40 kg P ha$^{-1}$ × 0 kg S ha$^{-1}$
$P_2S_1$ : 40 kg P ha$^{-1}$ × 10 kg S ha$^{-1}$
$P_2S_2$ : 40 kg P ha$^{-1}$ × 20 kg S ha$^{-1}$
$P_2S_3$ : 40 kg P ha$^{-1}$ × 30 kg S ha$^{-1}$
$P_3S_0$ : 60 kg P ha$^{-1}$ × 0 kg S ha$^{-1}$
$P_3S_1$ : 60 kg P ha$^{-1}$ × 10 kg S ha$^{-1}$
$P_3S_2$ : 60 kg P ha$^{-1}$ × 20 kg S ha$^{-1}$
$P_3S_3$ : 60 kg P ha$^{-1}$ × 30 kg S ha$^{-1}$

### 3.3 Experimental design and layout

The experiment consisted of four doses of P and four doses of S and was laid out in a two factor Randomized Complete Block Design (RCBD) with three replications. The size of plot was 4.0 × 3.0 m (12 m$^2$) where block to block and plot to plot distance was 0.75 m and 0.5 m, respectively. Row to row and plant to plant distance were also 20 cm and 20 cm, respectively, in each plot. So, the total plots were 48 (P 4 × S 4 × Replication 3). The layout of the experiment was presented in Appendix III.

## 3.4 Crop Management

### 3.4.1 Seed collection

Seeds of BRRI dhan56 were collected from Genetic Resource and Seed Division, BRRI, Joydebpur, Gazipur, Bangladesh.

### 3.4.2 Seed sprouting

Seeds were selected by following specific gravity method. Seeds were immersed into water in a bucket for 24 hours. These were then taken out of water and kept tightly in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

### 3.4.3 Preparation of seedling nursery

A common procedure was followed in raising seedlings in the seedbed. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. No fertilizer was used in the nursery bed.

### 3.4.4 Seed Sowing

Seeds were sown in the nursery seed bed on 8 July, 2013.

## 3.5 Land preparation for transplanting

The experimental field was opened on 25 July, 2013 and prepared by ploughing and cross ploughing with power tiller and country plough. Then the land was laddered with traditional tools. Thereafter, the land was ploughed and cross–ploughed and deep ploughing was obtained good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly before planting according to Fertilizer Recommendation Guide (BARC, 2005). After uniform leveling, the experimental plots were laid out according to the requirement of the design.

### 3.6 Fertilizer application

Phosphorus and Sulphur fertilizers were applied to each plot as per treatments. Fertilizer such as Urea and MoP were used as source for N and K, respectively. Phosphorus and Sulphur required for each unit plot were calculated from the rate of application as per treatments. Among the other fertilizer, one-third of urea and the entire required amounts of other fertilizers were applied as basal to the individual plots during final land preparation (BRRI, 2011). The fertilizers were incorporated into soil by spading. The second split of urea was applied at maximum tillering stage and the remaining split at panicle initiations stage. The rates and sources of different nutrients used in this experiment are given as below

**Nutrient elements, their sources, and doses used in the experiment**

| **Nutrient element** | **Source** | **Rate (Kg ha$^{-1}$)** |
|---|---|---|
| Sulphur | Gypsum (18% S) | 0, 10, 20 and 30 |
| Zinc | $ZnSO_4$ | 80 |
| Nitrogen | Urea (46% N) | 120 |
| Phosphorus | TSP (20% P) | 0, 20, 40 and 60 |
| Potassium | MoP (50% K) | 80 |

**Source:** BRRI 2011 (Fertilizer Recommended Guide)

### 3.7 Uprooting of seedlings

The seedbeds were made wet by application of water on the previous day before uprooting the seedlings. The seedlings were uprooted carefully without causing dry injury to the roots. The uprooted seedlings were kept on soft mud under shade.

### 3.8 Transplanting of seedlings

On 7th August 2013, 30 days old seedlings were transplanted in the experiment field keeping plant to plant distance 20 cm and row to row distance 20 cm. Gap filling was made up to 7 days after transplanting to maintain proper treatment and similar plant population density for every plot.

### 3.9 Intercultural operations

After transplanting of the seedlings, different operations as and when necessary were carried out for better growth and development of the plant.

#### 3.9.1 Weeding

Few weeds namely, durba, shama, chesra, maluncha and mutha were found in each plot after two weeks of transplanting. They were uprooted immediately by hand pulling.

### 3.10 Sampling and data collection

Sampling was done during growth stages and harvest. At each sampling five random hills from each plot were uprooted avoiding border hills and washed them in running tap water. Then the plant samples were carried to the laboratory and plant height and number of tiller were recorded.

### 3.11 Harvest and post harvest operations

Harvesting was done when 80–90% of the grains became golden in color. Five hills excluding border hills were randomly selected from each plot. Selected plants were cut at the ground level and were separately bundled and properly tagged for recording necessary data. Grain and straw yields were determined by harvesting the whole plot leave border and sampling area. The harvested crops were then threshed and cleaned. Grain and straw weights were recorded after proper sun drying. The harvested seeds of this experiment were stored in plastic airtight container for further investigation of seed qualitative parameters.

## 3.12 Parameters studied

### Growth, yield and yield contributing characters

(i) Plant height (cm)
(ii) Number of tillers hill$^{-1}$
(iii) Number of effective tillers hill$^{-1}$
(iv) Number of non effective tillers hill$^{-1}$
(v) Number of filled grains panicle$^{-1}$
(vi) Number of unfilled grains panicle$^{-1}$
(vii) 1000 grain weight (g)
(viii) Grain yield (t ha$^{-1}$)
(ix) Straw yield (t ha$^{-1}$)
(x) Biological yield (t ha$^{-1}$)
(xi) Harvest index (%)

## 3.13 Measurement of yield and yield contributing characters

### 3.13.1 Plant height (cm)

The effective plant height was considered from ground level to the tip of the leaf at vegetative phase and panicle at harvest stage. Plant height data was measured by a meter scale and converted into cm and recorded at 30 days interval from 25 DAT (days after transplanting) up to 85 DAT (days after transplanting) and at harvest.

### 3.13.2 Number of tillers hill$^{-1}$

Number of tillers hill$^{-1}$ were recorded at 25, 55, 85 DAT and at harvest from the randomly selected 5 hills where all the effective tillers and non effective tillers were considered for counting the total tillers at every data recording stages.

### 3.13.3 Number of effective tillers hill$^{-1}$

The panicles which had at least one grain was considered as effective tiller. The number of effective tillers of 5 hills was recorded and expressed as effective tillers number hill$^{-1}$ at harvest.

### 3.13.4 Number of non–effective tillers hill$^{-1}$

The tiller having no panicle was regarded as non-effective tiller. The number of ineffective tillers 5 hills$^{-1}$ was recorded and was expressed as non–effective tiller number hill$^{-1}$ at harvest.

### 3.13.5 Number of filled grains panicle$^{-1}$

Filled grain was considered to be filled if any kernel was present there in. Number of filled grain was recorded from randomly selected 5 hills and converted into filled grains panicle$^{-1}$.

### 3.13.6 Number of unfilled grain panicle$^{-1}$

Number of unfilled grains panicle$^{-1}$ means the absence of any kernel inside in and such grains present on each hill were counted from the randomly selected 5 hill.

### 3.13.7 Thousand grain weight (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

### 3.13.8 Grain yield (t ha$^{-1}$)

Grain yield was determined from the whole plot and expressed as t ha$^{-1}$ on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

### 3.13.9 Straw yield (t ha$^{-1}$)

Straw yield was determined from the whole plot. After threshing, the sub–sample was oven dried to a constant weight and finally converted to t ha$^{-1}$.

### 3.13.10 Biological yield (t ha$^{-1}$)

Biological yield is the sum of grain and straw yield which was recorded into kg plot$^{-1}$ and finally converted into t ha$^{-1}$. The biological yield was calculated by using the following formula: Biological yield= Grain yield + straw yield.

### 3.13.11 Harvest index (%)

Harvest index is the ratio of the economic yield to the total biological yield of a crop. The harvest index was calculated by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,

Economic yield = Grain yield

Biological yield = Grain yield + Straw yield

## 3.14 Statistical analyses

Data recorded for yield and yield contributing characters and seed quality characters were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of MSTAT–C computer package programme developed by Russel (1986). The mean differences among the treatments were evaluated with DMRT test (Gomez and Gomez, 1984).

# CHAPTER IV

# RESULTS AND DISCUSSION

The present research work was to investigate the effect of P and S on the performance of growth and yield of rice cv. BRRI dhan56 under the Agro-Ecological Zone of “The Modhupur Tract”, AEZ-28. The results on growth, yield and yield attributing characters of BRRI dhan56 have been presented in Tables 1 to 15 and Figures 1 to 6. Analysis of variance (ANOVA) results was also presented in Appendices IV to VII. Among the studied characters, plant height (cm) and number of tillers hill$^{-1}$ were recorded at 25, 55, 85 DAT and at harvest while effective and non–effective tillers hill$^{-1}$, number of filled and unfilled grains panicle$^{-1}$, 1000–grains weight (g), grain yield (t ha$^{-1}$), straw yield (t ha$^{-1}$), biological yield (t ha$^{-1}$) and harvest index (%) were recorded at the time of harvest and their details results were described under the following sub–headings. A detailed discussion on the presented results and possible interpretations are given in this chapter under the following headings.

## 4.1 Responses of P and S on growth and yield of rice cv. BRRI dhan56

### 4.1.1 Plant height (cm)

#### 4.1.1.1 Effect of phosphorus

Plant height is one of the most efficient characters among the yield and yield contributing characters for getting the higher yield of rice due to the plant height is a key of higher straw yield. Growth of rice plant was greatly influenced by different doses of phosphorus. In this study, Application of different doses of phosphorus exerted significant difference at every stages of data recording due to phosphorus application (Fig. 1). The tallest plant (22.70, 95.81, 105.5 and 109.70 cm) was observed in 40 kg $P_2O_5$ (P) ha$^{-1}$ at 25, 55, 85

DAT and at harvest, respectively, which was significantly differed from other P doses.

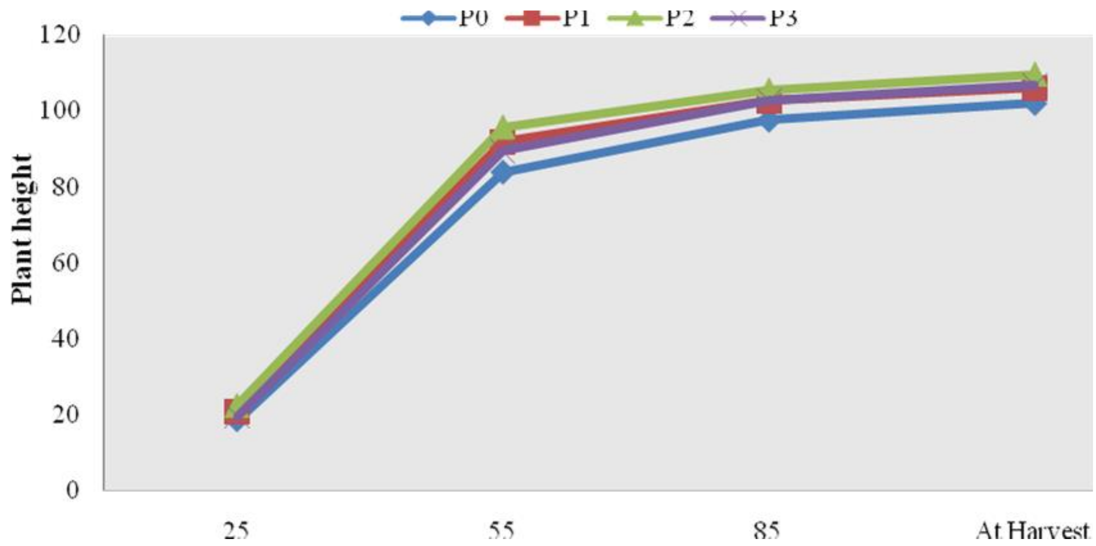


**Fig. 1. Effect of phosphorus on plant height at different days after transplanting** (SE= 0.63, 1.16, 1.17 and 1.28 at25, 55, 85 DAT and at harvest)

In contrast, $P_0$ (control) produced significantly the shortest plant (18.71, 84.07, 97.78 and 102.20 cm) at these stages, respectively. These results indicated that the plant height increased progressively with the increment of growth stage and also with the increased doses of phosphorus up to 40 $P_2O_5$ (Fig. 1). However, plant height rapidly increased from 25 to 55 DAS and thereafter it increased gradually up to harvest. Similar findings were also obtained by Rasavel Ravichandran (2013) where they reported that plant height of rice significantly influenced by phosphorus levels where $P_2O_5$ @ 50 kg $ha^{-1}$ observed the tallest plant (89.5 cm) in neutral soil. Yose (2012) and Alam *et al*. (2009) and many other scientists also found significant variation in plant height due to the application of phosphorus fertilizer where plant height significantly increased with increasing the phosphorus levels.

#### 4.1.1.2 Effect of sulphur

Plant height differed significantly due to the application of different level of sulphur throughout the growing season except at 55 DAT (Fig. 2). At 25 DAT, the tallest plant (22.79 cm) was found in 20 kg S $ha^{-1}$ while 30 kg S $ha^{-1}$ of sulphur ($S_1$) recorded the statistically similar shortest plant (21.67 cm). However, 20 kg S $ha^{-1}$ ($S_2$) produced the tallest plant (92.70, 105.10 and 109.40) at 55, 85 DAT and at harvest, respectively and $S_0$ obtained the shortest plant (89.10, 100.40 and 103.20 cm) at 55, 85 DAT and at harvest, respectively. On the basis of this result, it was showed that the plant height increase up to 20 kg S $ha^{-1}$ and then it decreased. Similar result was also observed by Islam *et al*. (2009) who conducted an experiment to evaluate the effects of different rates and sources of sulphur on the yield, yield components, nutrient content and nutrient uptake of rice (cv. BRRI dhan30) and the longest plant was found from 16 kg S $ha^{-1}$ applied as gypsum while the shortest plant was noticed with S control treatment.

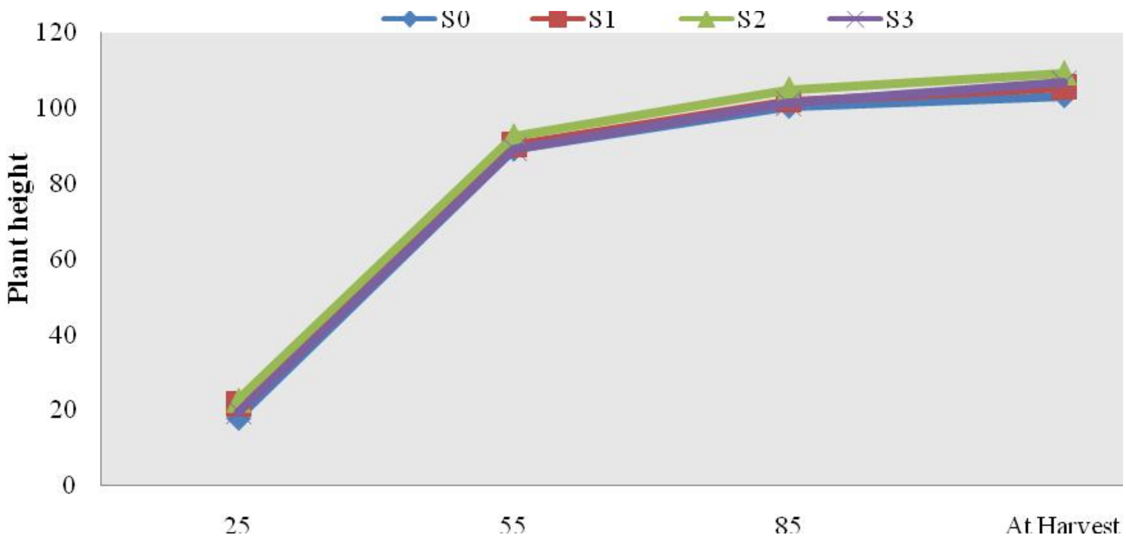


**Fig. 2. Effect of sulphur on plant height at different days after transplanting** (SE= 0.63, 1.16, 1.17 and 1.28 at 25, 55, 85 DAT and at harvest)

### 4.1.1.3 Interaction effect of phosphorus and sulphur

Interaction effect between various doses of P and S was significantly influenced at 5% level of probability on plant height at all the growth stages in this study (Table 1). As a result, the tallest plant (24.17, 97.18, 107.30 and 111.60 cm) was found from the interaction treatment of 40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$ ($P_2S_2$) at 25, 55, 85 DAT and at harvest, respectively which was statistically differed from other interactions at those stages.

**Table 1. Interaction effect of phosphorus and sulphur on plant height at different days after transplanting**

| Treatments | Plant height (cm) at different days after transplanting (DAT) | | | |
|---|---|---|---|---|
| | 25 | 55 | 85 | At Harvest |
| $P_0S_0$ | 15.12 g | 83.33 f | 93.23 d | 95.65 e |
| $P_0S_1$ | 20.66 cd | 82.15 f | 97.58 c | 99.63 d |
| $P_0S_2$ | 21.78 bc | 87.43 e | 103.80 ab | 108.10 ab |
| $P_0S_3$ | 17.28 ef | 83.35 f | 96.52 cd | 105.50 bc |
| $P_1S_0$ | 18.86 de | 91.15 d | 101.80 b | 102.10 cd |
| $P_1S_1$ | 21.65 bc | 92.00 cd | 102.80 b | 106.90 b |
| $P_1S_2$ | 22.77 ab | 93.35 b-d | 104.80 ab | 109.10 ab |
| $P_1S_3$ | 20.51 cd | 91.43 cd | 102.30 b | 106.50 b |
| $P_2S_0$ | 21.67 bc | 94.97 a-d | 104.60 ab | 108.90 ab |
| $P_2S_1$ | 23.06 ab | 95.83 ab | 105.30 ab | 109.40 ab |
| $P_2S_2$ | 24.17 a | 97.18 a | 107.30 a | 111.60 a |
| $P_2S_3$ | 21.91 bc | 95.25 a-c | 104.80 ab | 109.00 ab |
| $P_3S_0$ | 16.25 fg | 86.95 e | 101.80 b | 106.00 bc |
| $P_3S_1$ | 21.33 bc | 91.49 cd | 102.50 b | 106.60 b |
| $P_3S_2$ | 22.44 abc | 92.84 b-d | 104.40 ab | 108.80 ab |

| | | | | |
|---|---|---|---|---|
| **$P_3S_3$** | 18.70 de | 87.06 e | 101.90 b | 106.20 b |
| **CV (%)** | 6.13 | 2.58 | 2.28 | 2.42 |
| **SE** | 0.63 | 1.16 | 1.17 | 1.28 |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

Similarly, the shortest plant (15.12, 83.33, 93.23 and 95.65 cm) was found from interaction of both control fertilizers, $P_0S_0$ (without phosphorus and sulphur) at these stages, respectively which was statistically similar with interaction effect of 0 kg P ha$^{-1}$ with both 10 and 30 kg S ha$^{-1}$ (82.15 and 83.35 cm) at 55 DAT (Table 1). These results revealed that the interaction effect of 40 kg P and 20 kg S ha$^{-1}$ was highly significant than other interactions to supply the adequate soil nutrient with keeping the soil fertility, kept the favorable soil moisture, reduce the soil pH, maintenance the higher photosynthesis as well as to create the better growth condition for better growth of BRRI dhan56.

### 4.1.2 Number of tillers hill$^{-1}$

#### 4.1.2.1 Effect of phosphorus

Tiller production are directly related to grain and straw yield in case of the more tillers produced more panicle, more grains which ultimately increase the grain and straw yield of rice. Number of total tillers hill$^{-1}$ showed significant difference due to the different level of phosphorus application at different days after transplanting (Fig. 3).

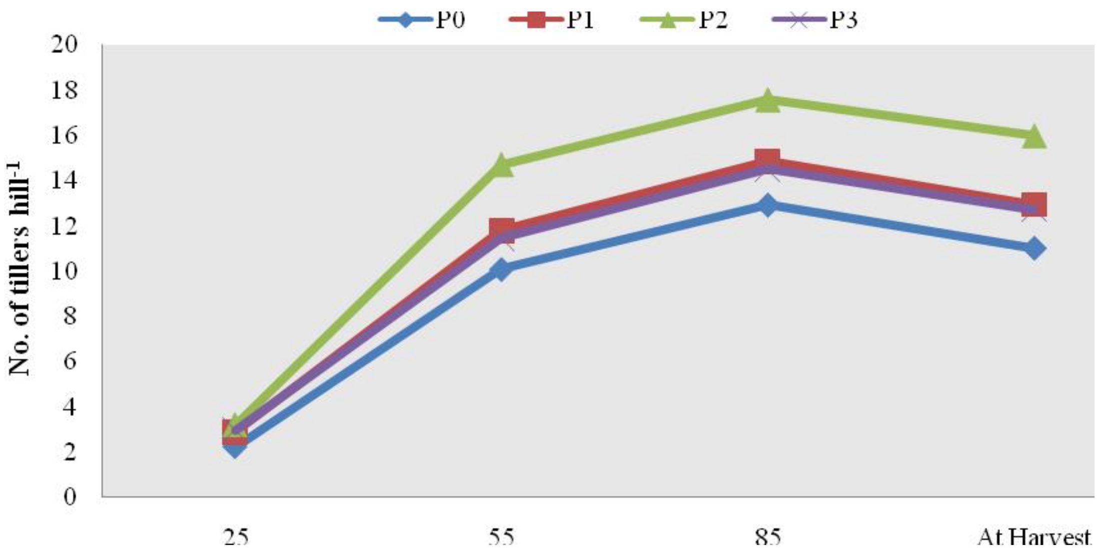


**Fig. 3. Effect of phosphorus (P) on number of tillers hill$^{-1}$ at different days after transplanting** (SE= 0.12, 0.24, 0.28 and 0.36 at 25, 55, 85 DAT and at harvest)

From the Fig. 3, it was appeared that the phosphorus @ 40 kg ha$^{-1}$ ($P_2$) recorded the maximum total tillers hill$^{-1}$ (3.20, 14.72, 17.58 and 15.99) at 25, 55, 85 DAT and at harvest, respectively which was significantly differed from other phosphorus level (Fig. 3). In contrast, the minimum total tillers hill$^{-1}$ (2.24, 10.07, 12.92 and 11.01) was found in without phosphorus fertilizer ($P_0$) at those stages, respectively which was also statistically differed from other interactions at these stages. These results indicated that tiller production significantly increased up to 85 DAT and thereafter it decreased at harvest due to its mortality at the later stages. The result also showed that 40 kg P ha$^{-1}$ always produced maximum number of total tillers hill$^{-1}$ at all growth stages while without phosphorus gave the lowest tiller production. The present finding of the study was agreed to the findings of Rasavel and Ravachandran (2013) who reported that the maximum number of tillers hill$^{-1}$ (17.2) was noticed with application of 50 kg $P_2O_5$ ha$^{-1}$ in neutral soils. Similarly, Yose (2012) found that the tiller production increased significantly with phosphorus fertilizer. Alam *et al*. (2009) also found that the number of tillers hill$^{-1}$ differed significantly with the application of P fertilizer.

#### 4.1.2.2 Effect of sulphur

Analysis of variance data regarding to tiller production hill$^{-1}$ was affected significantly due to the various levels of sulphur application at 25, 55, 85 DAT and at harvest (Fig. 4). Among the sulphur levels, the maximum total tillers hill$^{-1}$ (4.07, 13.60, 16.12 and 14.75) was recorded in 20 kg S ha$^{-1}$ ($S_2$) at 25, 55, 85 DAT and at harvest, respectively which was significantly differed from others (Fig. 4).

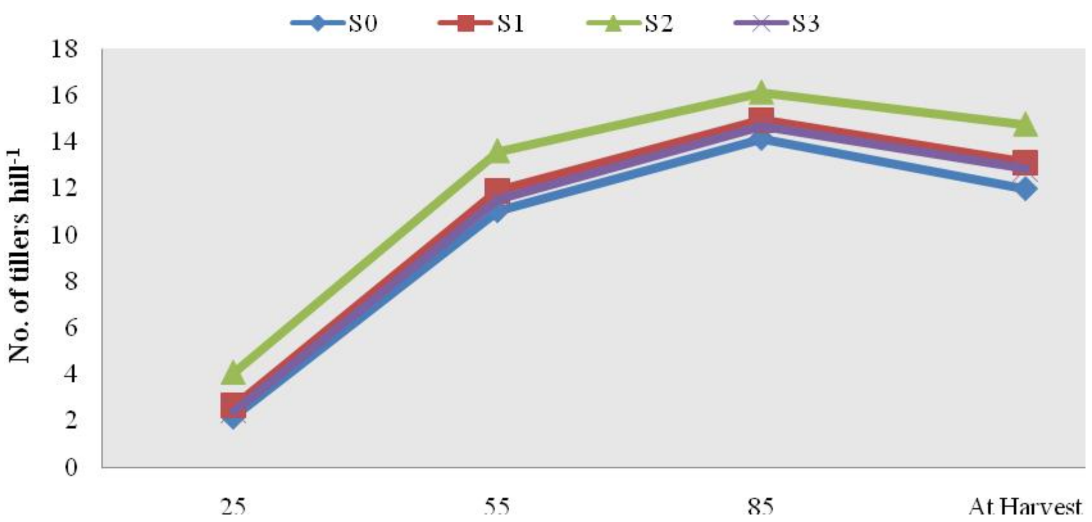


**Fig. 4. Effect of sulphur (S) on number of tillers hill$^{-1}$ at different days after transplanting** (SE= 0.12, 0.24, 0.28 and 0.36 at 25, 55, 85 DAT and at harvest)

On the other hand, the minimum total tillers hill$^{-1}$ (2.17, 11.03, 14.14 and 11.98) was found in control ($S_0$) at those stages, respectively whereas statistically identical lower total tillers hill$^{-1}$ (2.42, 11.50, 14.67 and 12.83) was obtained in higher sulphur level, $S_3$(30 kg ha$^{-1}$) at 25, 55, 85 DAT and at harvest, respectively. These result revealed that number of total tillers hill$^{-1}$ increased with the increasing levels of S up to 20 kg ha$^{-1}$ after that it was decreased at 30 kg S ha$^{-1}$. Similarly, tiller production unexpectedly decreased at harvest due to the higher tiller mortality for maturity at harvest.

### 4.1.2.3 Interaction effect of phosphorus and sulphur

A significant variation was also found during the growth period due to interaction effect between phosphorus and sulphur fertilizers regarding number of tillers hill$^{-1}$ (Table 2). Among the interaction effects, 40 kg P ha$^{-1}$ with the combination of 20 kg S ha$^{-1}$ ($P_2S_2$) recorded the maximum tillers hill$^{-1}$ (4.33, 16.23, 18.10 and 17.50) at 25, 55, 85 DAT and harvest, respectively which was statistically differed from other interactions of both fertilizers at every data recording stages. On the other hand, the lowest number of tillers hill$^{-1}$ (1.40, 9.19, 11.85 and 9.59) was observed from the interaction effect of control $P_0S_0$ (without P and S) fertilizers at 25, 55, 85 DAT and at harvest, respectively which was statistically identical with $P_0S_1$ at 25 DAT; $P_0S_1$ and $P_0S_3$ at 55 DAT (Table 2). These results revealed that all the interaction treatments showed increment tillers production hill$^{-1}$ up to 85 DAT, thereafter it decrease at harvest which might be due to the tiller mortality for maturity at harvest. The interaction treatment of $P_2S_2$ (40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$) obtained the maximum tillers due to the proper nutrient supply to the plant which ultimately reduced the tiller mortality at harvest.

**Table 2. Interaction effect of phosphorus and sulphur on number of tillers hill$^{-1}$ at different days after transplanting**

| Treatments | No. of tillers hill$^{-1}$ at different days after transplanting (DAT) | | | |
|---|---|---|---|---|
| | 25 | 55 | 85 | At Harvest |
| $P_0S_0$ | 1.40 j | 9.19 h | 11.85 h | 9.59 i |
| $P_0S_1$ | 1.74 ij | 9.74 h | 12.73 g | 10.74 h |

| | | | | |
|---|---|---|---|---|
| **$P_0S_2$** | 3.81 b | 11.71 e | 14.27 de | 12.55 ef |
| **$P_0S_3$** | 2.03 hi | 9.63 h | 12.83 fg | 11.15 gh |
| **$P_1S_0$** | 2.29 gh | 10.42 g | 13.62 ef | 11.27 gh |
| **$P_1S_1$** | 2.82 c-e | 11.87 e | 14.93 d | 13.13 e |
| **$P_1S_2$** | 4.02 ab | 13.47 cd | 16.33 c | 14.73 cd |
| **$P_1S_3$** | 2.42 fg | 11.37 ef | 14.53 de | 12.63 ef |
| **$P_2S_0$** | 2.60 d-g | 13.90 c | 17.20 b | 15.17 b-d |
| **$P_2S_1$** | 3.13 c | 14.63 b | 17.70 ab | 15.90 b |
| **$P_2S_2$** | 4.33 a | 16.23 a | 18.10 a | 17.50 a |
| **$P_2S_3$** | 2.73 d-f | 14.13 bc | 17.30 ab | 15.40 bc |
| **$P_3S_0$** | 2.38 f-h | 10.63 g | 13.90 e | 11.90 fg |
| **$P_3S_1$** | 2.91 cd | 11.37 ef | 14.40 de | 12.63 ef |
| **$P_3S_2$** | 4.11 ab | 12.97 d | 15.80 c | 14.23 d |
| **$P_3S_3$** | 2.51 efg | 10.87 fg | 14.00 e | 12.13 efg |
| **CV (%)** | 8.39 | 3.92 | 3.74 | 5.41 |
| **SE** | 0.12 | 0.24 | 0.28 | 0.36 |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

### 4.1.3 Number of effective tillers hill$^{-1}$

#### 4.1.3.1 Effect of phosphorus

Among the yield components, productive or effective tillers are very important for obtaining the higher grain yield of rice in case of the final yield is mainly a function of the number of panicles bearing tillers per unit area. As evident from the analysis of variance data presented in Appendix VI, effective tillers hill$^{-1}$

exerted significant difference among the different phosphorus levels (Table 3). From the Table 3, it was noticed that the maximum effective tillers hill$^{-1}$ (13.67) was observed in 40 kg P ha$^{-1}$ ($P_2$) which was significantly differed from other phosphorus treatments. Similarly, control treatment ($P_0$) recorded the lowest number of effective tillers hill$^{-1}$ (7.98) which was also statistically differed from other P levels. These results revealed that variation in phosphorus application ultimately gave the differentiation in tiller production. It was also observed that the production of effective tillers significantly improved with the increase of applied phosphorus levels in this study. These variation in effective tiller production may be also found due to the higher doses of phosphorus would be more efficient than lower doses of phosphorus to soil fertility, adequate N supply, reduce soil pH and initiate favorable condition for better growth as well as the maximum effective tillers production were achieved. Yose (2012) also found similar results with the present study in case of they also found significant increase of fertile tiller with phosphorus fertilizer. Similarly, Yosef (2013a,b) reported that the effective tillers hill$^{-1}$ of rice varied significantly due to P fertilizer application where tiller production was highly responsive to phosphorus. They found that the maximum fertile tiller percentage was (79.54%) observed for 90 kg ha$^{-1}$ phosphorus fertilizer and minimum of that was (66.73) obtained for (control) 0 kg ha$^{-1}$ phosphorus fertilizer.

#### 4.1.3.2 Effect of sulphur

Analysis of variance data regarding to effective tiller production hill$^{-1}$ showed significant difference among the effects of different sulphur levels (Appendix VI and Table 4). Among the sulphur levels, it was noticed that the maximum effective tillers hill$^{-1}$ (12.12) was observed in 20 kg S ha$^{-1}$ ($S_2$) which was significantly differed from other sulphur levels. In contrast, control treatment

($S_0$) recorded the minimum effective tillers hill$^{-1}$ (9.37) which was statistically identical (9.47) with the treatment $S_3$ 30 kg ha$^{-1}$. Islam *et al*. (2009) also reported the similar results where the effective tillers hill$^{-1}$ was significantly influenced due to application of sulphur where 16 kg S ha$^{-1}$ recorded the maximum effective tillers hill$^{-1}$.

#### 4.1.3.3 Interaction effect of phosphorus and sulphur

The data on number of effective tillers hill$^{-1}$ was significantly influenced between the interaction effect of phosphorus and sulphur at harvest (Appendix VI and Table 5). The maximum number of effective tillers hill$^{-1}$ (15.53) was found from the interaction effect between 40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$ ($P_2S_2$) which was statistically differed from other interactions. In contrast, interaction effect of both control fertilizers, $P_0S_0$ (0 kg P ha$^{-1}$ and 0 kg S ha$^{-1}$) obtained the minimum effective tillers hill$^{-1}$ (7.17) at harvest which was also statistically differed from other interactions. These results showed that all the interactions were statistically differed with each other whereas interaction effect of 40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$ were more effective to reduce the possibility of tiller mortality by supplying the proper soil nutrient to the plant at harvest which ultimately produced more effective tillers in this study.

### 4.1.4 Number of non effective tillers hill$^{-1}$

#### 4.1.4.1 Effect of phosphorus

Analysis of variance data on non effective tillers hill$^{-1}$ presented in Appendix IV indicated significant variation due to the effect of different doses of phosphorus at harvest (Table 3). As evident from the Table 3, the maximum non effective tillers hill$^{-1}$ (3.85) was found in control ($P_0$) while the minimum non effective tillers hill$^{-1}$ (2.33) was obtained in 40 kg P ha$^{-1}$ ($P_2$) (Table 3). The variation in production of non effective tillers was found due to the variation in phosphorus levels which ensure the differentiation in tiller mortality possibility at harvest. These results also revealed that 40 kg ha$^{-1}$ phosphorus was more efficient to produce minimum number of non effective tillers which will contribute to greater grain and straw yield. Non effective tillers did not produce any panicle as well as filled grain which ultimately decreased the final grain yield also. Similarly, Yosef (2013a,b) found that the 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. Similar findings was also found by Rasavel *et al*. (2013), Yose (2012), Alam *et al*. (2009) where they found that control treatment produced significantly the maximum non effective tillers hill$^{-1}$.

**4.1.4.2 Effect of sulphur**

Number of non–effective tillers hill$^{-1}$ revealed significant difference due to the application of sulphur in this study (Appendix IV and Table 4). The maximum non–effective tillers hill$^{-1}$ (3.38) was observed from the highest dose of sulphur $S_3$ (60 kg ha$^{-1}$) at harvest while lowest dose of sulphur $S_1$ (10 kg S ha$^{-1}$) and without or control sulphur $S_0$ (0 kg S ha$^{-1}$) recorded the statistically identical to the second highest non effective tillers hill$^{-1}$ (3.30 and 3.25, respectively) at harvest. As the result indicates, 20 kg ha$^{-1}$ S ($S_2$) obtained the lowest non effectively tillers hill$^{-1}$ (2.83) at harvest. The variation in production of non effective tillers was found due to the variation of application levels of sulphur. In case of soil nutrient, soil moisture and pH, photosynthesis, sulphur diffusion etc. varied due to the variation of sulphur in this experiment.

**4.1.4.3 Interaction effect of phosphorus and sulphur**

There was a significant variation found due to the application of interaction effect of both phosphorus and sulphur fertilizer in respect to non effective tiller production in this study (Appendix IV and Table 5). From the Table 5, it was found that the maximum number of non effective tillers hill$^{-1}$ (3.97) was produced from $P_0S_3$ (0 kg ha$^{-1}$ P with 30 kg ha$^{-1}$ S) at harvest while this interaction treatment were statistically differed from other interactions of both fertilizers. Similarly, the minimum number of non effective tillers hill$^{-1}$ (1.97) was found in $P_2S_2$ (40 kg P ha$^{-1}$ with the combination of 20 kg S ha$^{-1}$) which was also statistically differed from other interactions.

### 4.1.5 Number of filled grains panicle$^{-1}$

#### 4.1.5.1 Effect of phosphorus

Different levels of phosphorus increased the number of filled grains panicle$^{-1}$ of BRRI dhan56 up to 40 kg ha$^{-1}$ in this study (Appendix IV and Table 3). The filled grains panicle$^{-1}$ due to different doses of phosphorus varied from 110.0 to 138.60 (Table 3). The maximum number of filled grains panicle$^{-1}$ was obtained from $P_2$ treatment (40 kg P ha$^{-1}$) which was statistically differed from others. On the other hand, the minimum number of filled grains panicle$^{-1}$ was observed in $P_0$ (control treatment) which was also statistically differed from other treatments. In case of the treatment produced significantly the maximum total and effective tiller as well as the minimum unfilled grains production which ultimately confirmed the maximum production of filled grains panicle$^{-1}$. Rasavel *et al.* (2013) studied the similar findings with the present study. They reported that the maximum 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. Similarly, Yose (2012) found that the total grain increased significantly with phosphorus fertilizer. These results was also similar to the findings of Alam *et al.* (2009) who reported that the maximum filled grains panicle$^{-1}$ differed significantly with the application of P fertilizer while phosphorus at 72 kg $ha^{-1}$ ($P_3$) showed the maximum and without P gave the lowest results.

#### 4.1.5.2 Effect of sulphur

Number of filled grains $panicle^{-1}$ did not differed significantly due to the application of different levels of sulphur in T-*aman* rice cv. BRRI dhan56 in this experiment (Appendix VI and Table 4). However, numerically the maximum filled grains $panicle^{-1}$ (127.00) was recorded in $S_2$ (20 kg S $ha^{-1}$) and minimum (119.6) was found in control ($S_0$) but they were not statistically different (Table 4).

#### 4.1.5.3 Interaction effect of phosphorus and sulphur

Analysis of variance data regarding to filled grains $panicle^{-1}$ presented in Appendix VI and indicated significant variation due to the interaction effect between phosphorus and sulphur (Table 5). Among the interaction treatments, the maximum number of filled grains $panicle^{-1}$ (141.40) was found in interaction of $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) which was statistically significant from other interactions. Similarly, interaction effect of both control fertilizers $P_0S_0$ (without Phosphorus and Sulphur) obtained the minimum number of filled grains $panicle^{-1}$ (108.8) which was statistically similar with the interactions of $P_0S_3$ (0 kg P $ha^{-1}$ with 30 kg S $ha^{-1}$) (108.90) and $P_0S_1$(0 kg P $ha^{-1}$ with 10 kg S $ha^{-1}$) (109.4).

### 4.1.6 Number of unfilled grains $panicle^{-1}$

#### 4.1.6.1 Effect of phosphorus

The variations in the number of unfilled grains $panicle^{-1}$ due to different doses of Phosphorus were significant at harvest in this study (Appendix IV). The significant variation result regarding to unfilled grains $panicle^{-1}$ was presented in Table 3 where it was showed that the unfilled grains panicle$^{-1}$ varied from 8.45 to 15.93. The maximum unfilled grains panicle$^{-1}$ was produced due to ($P_2$) 40 kg P ha$^{-1}$ and the lowest unfilled grains panicle$^{-1}$ was obtained in 20 kg S ha$^{-1}$ ($S_2$) whereas all the phosphorus levels were statistically significant with each other (Table 3). The variation in unfilled grains panicle$^{-1}$ was found due to the variation in phosphorus level. Phosphorus @ 40 kg ha$^{-1}$ produced significantly the maximum effective tillers and more panicle which confirmed the minimum unfilled grains and it will be contribute to maximize the grain production of rice cv. BRRI dhan56 in this study. Similar findings were also obtained by Alam *et al*. (2009). They found that unfilled grains panicle$^{-1}$ differed significantly with the application of P fertilizer while it was the maximum in 72 kg P ha$^{-1}$ and minimum in without P.

**Table 3. Effect of phosphorus on effective and non effective tillers hill$^{-1}$ and filled and unfilled grains panicle$^{-1}$ at harvest**

| Phosphorus levels (kg ha$^{-1}$) | Number of effective tillers hill$^{-1}$ | Number of non effective tillers hill$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ |
|---|---|---|---|---|
| **$P_0$** | 7.98 d | 3.85 a | 110.00 d | 15.93 a |
| **$P_1$** | 10.02 b | 3.21 c | 120.90 b | 13.21 c |
| **$P_2$** | 13.67 a | 2.33 d | 138.60 a | 8.45 d |
| **$P_3$** | 9.34 c | 3.38 b | 116.90 c | 14.03 b |
| **CV (%)** | **1.03** | **1.14** | **0.96** | **2.29** |
| **SE** | **0.03** | **0.009** | **0.34** | **0.09** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

### 4.1.6.2 Effect of sulphur

Number of unfilled grains panicle$^{-1}$ differed significantly due to the effect of sulphur (Appendix IV and Table 4). Among the sulphur treatments, the maximum number of unfilled grains panicle$^{-1}$ (13.42) was recorded in $S_1$ treatment (10 kg S ha$^{-1}$) which was statistically similar with $S_0$ (13.00) and $S_3$

(30 kg S ha$^{-1}$) (13.17). As a result, the minimum number of unfilled grains panicle$^{-1}$ (12.04) was recorded from $S_2$ 20 kg S ha$^{-1}$ which was also statistically followed by (control) $S_0$ and (30 kg S ha$^{-1}$) $S_3$ (Table 4). These results showed that $S_2$ (20 kg S ha$^{-1}$) was highly significant to reduce unfilled grains due to maximum productive tillers and more filled grains were obtained under this treatment.

**Table 4. Effect of sulphur on effective and non effective tillers hill$^{-1}$ and filled and unfilled grains panicle$^{-1}$ at harvest**

| Sulphur levels (kg ha$^{-1}$) | Number of effective tillers hill$^{-1}$ | Number of non effective tillers hill$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ |
|---|---|---|---|---|
| **$S_0$** | 9.37 c | 3.25 b | 119.60 | 13.00 ab |
| **$S_1$** | 10.05 b | 3.30 b | 120.20 | 13.42 a |
| **$S_2$** | 12.12 a | 2.83 c | 127.00 | 12.04 b |
| **$S_3$** | 9.47 c | 3.38 a | 119.70 | 13.17 ab |
| **CV (%)** | **1.03** | **1.14** | **0.96** | **2.29** |
| **SE** | **0.09309** | **0.02236** | **2.339** | **0.3735** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

### 4.1.6.3 Interaction effect of phosphorus and sulphur

The data on unfilled grains panicle$^{-1}$ showed significant difference among the interaction effect between phosphorus and sulphur application levels (Appendix IV and Table 5). The unfilled grains panicle$^{-1}$ varied from 7.87 to 16.27 due to interaction effect of phosphorus and sulphur fertilizers. The minimum number of unfilled grains panicle$^{-1}$ (16.27) was found in interaction of $P_0S_1$ (0 kg P ha$^{-1}$ and 10 kg S ha$^{-1}$) which was followed by the interaction effects of $P_0S_0$ (0 kg P and 0 kg S ha$^{-1}$) (15.85) and $P_0S_3$ (0 kg P ha$^{-1}$ and 30 kg S ha$^{-1}$) (16.02) whereas interaction effect of $P_0S_1$ and $P_0S_3$ were statistically identical to produced unfilled grains panicle$^{-1}$. On the other hand, interaction effect of $P_2S_2$ (40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$) obtained the minimum number of unfilled grains panicle$^{-1}$ (7.87) which was statistically differed from other interactions (Table 5).

**Table 5. Interaction effect of phosphorus and sulphur on number of effective and non effective tillers hill$^{-1}$, number of filled and unfilled grains panicle$^{-1}$ production at harvest**

| Treatment combinations | Number of effective tillers hill$^{-1}$ | Number of non effective tillers hill$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ |
|---|---|---|---|---|
| $P_0S_0$ | 7.17 o | 3.83 c | 108.80 h | 15.85 ab |
| $P_0S_1$ | 7.83 m | 3.90 b | 109.40 h | 16.27 a |
| $P_0S_2$ | 9.63 h | 3.70 d | 112.80 g | 15.58 b |
| $P_0S_3$ | 7.27 n | 3.97 a | 108.90 h | 16.02 ab |
| $P_1S_0$ | 9.10 j | 3.30 h | 117.60 e | 13.55 fg |
| $P_1S_1$ | 9.80 g | 3.33 h | 118.20 e | 13.97 def |
| $P_1S_2$ | 11.97 e | 2.77 j | 130.20 c | 11.62 h |
| $P_1S_3$ | 9.20 i | 3.43 g | 117.80 e | 13.72 ef |
| $P_2S_0$ | 12.80 d | 2.37 l | 137.40 b | 8.45 i |
| $P_2S_1$ | 13.43 b | 2.47 k | 138.00 b | 8.87 i |
| $P_2S_2$ | 15.53 a | 1.97 m | 141.40 a | 7.87 j |
| $P_2S_3$ | 12.90 c | 2.50 k | 137.60 b | 8.62 i |
| $P_3S_0$ | 8.40 l | 3.50 f | 114.50 fg | 14.15 cde |
| $P_3S_1$ | 9.13 j | 3.50 f | 115.00 f | 14.57 c |
| $P_3S_2$ | 11.33 f | 2.90 i | 123.60 d | 13.08 g |
| $P_3S_3$ | 8.50 k | 3.63 e | 114.60 fg | 14.32 cd |
| **CV (%)** | **1.03** | **1.14** | **0.96** | **2.29** |
| **SE** | **0.02** | **0.02** | **0.68** | **0.17** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

### 4.1.7 1000-grain weight (g)

#### 4.1.7.1 Effect of phosphorus

Data revealed that 1000-grain weight differed significantly due to the main effect of phosphorus fertilizer presented in Fig. 5. Results revealed that the different phosphorus levels increased the 1000-grain weight of BRRI dhan56 over control whereas treatment $P_2$ (40 kg P $ha^{-1}$) noticed the highest weight of thousand grains (26.73 g) which was statistically similar with $P_1$ (25.67 g).

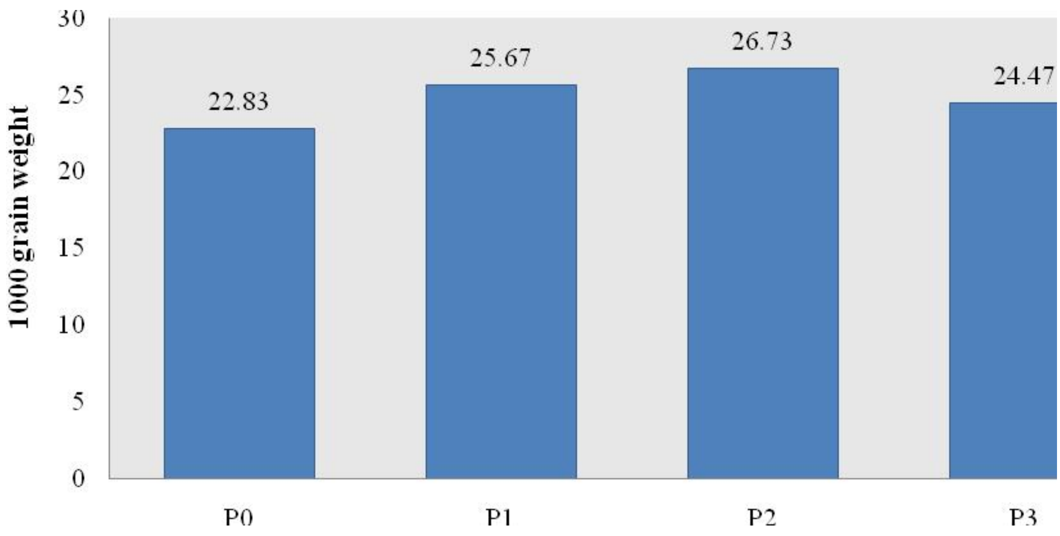


**Fig. 5. Effect of phosphorus (P) on 1000-grain weight at harvest** (SE=0.58)

In contrast, $P_0$ (control) recorded the lowest weight of thousand grains (22.83 g). These results revealed that application of 40 kg P $ha^{-1}$ was highly effective to produced adequate soil nutrients and manufacture favorable growing condition for rice plant which was helpful to produced more filled grain, larger grain, as well as higher weight of grain. Similarly Yose (2012) found that the 1000-grain weight increased significantly with phosphorus fertilizer. Alam *et al*. (2009) also found similar results with my study where they reported that 1000-grain weight differed significantly with the application of P fertilizer while highest weight of 1000-grain were taken from phosphorus at 72 kg $ha^{-1}$ and without P gave the lowest weight.

#### 4.1.7.2 Effect of sulphur

1000-grain weight was also differed significantly due to the application of different levels of sulphur in this study (Fig. 6). Results revealed that the different sulphur levels increased the 1000-grain weight of BRRI dhan56 over control whereas treatment $S_2$ (20 kg S $ha^{-1}$) noticed the highest weight of 1000 grains (27.52 g) and $S_0$ (control) recorded the lowest weight of thousand grains (22.21 g) (Fig. 8). On the other hand, $S_1$ (10 kg S $ha^{-1}$) recorded the second highest weight of 1000 grains (24.31 g) which was statistically similar (25.66 g) with $S_3$ (30 kg S $ha^{-1}$). These results revealed that application of 20 kg S $ha^{-1}$ was highly effective to produce the highest 1000-grain weight whereas higher or lesser from that level decreased the thousand grain weight.

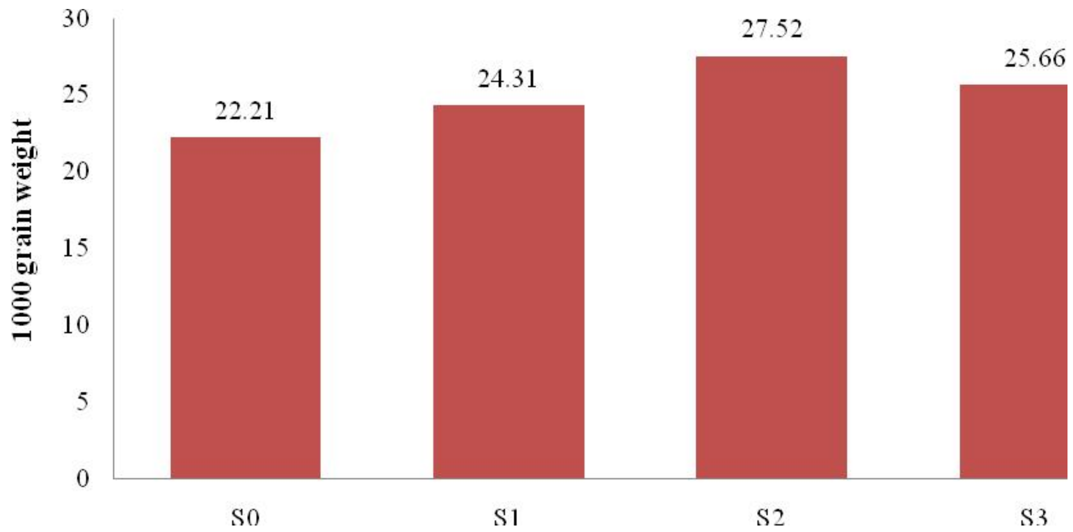


**Fig. 6. Effect of sulphur (S) on 1000-grain weight at harvest** (SE=0.58)

### 4.1.7.3 Interaction effect of phosphorus and sulphur

Analysis of variance data on 1000-grain weight varied significantly among the interactions effect of application of phosphorus and sulphur (Table 6). From the Table 6, it was observed that the highest thousand grain weight (30.75 g) was found from $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) which was statistically similar (30.00 g) with $P_2S_3$ (40 kg P $ha^{-1}$ and 30 kg S $ha^{-1}$). On the other hand, the lowest weight of 1000 grain (20.60 g) was found from the interaction effect $P_3S_0$ (60 kg P $ha^{-1}$ and 0 kg S $ha^{-1}$) which was statistically similar with $P_0S_0$ (0 kg P $ha^{-1}$ and 0 kg S $ha^{-1}$) (Table 6).

**Table 6. Interaction effect of phosphorus and sulphur on 1000-grain weight at harvest**

| Treatment combinations | 1000-grain weight |
|---|---|
| **$P_0S_0$** | 22.02 gh |
| **$P_0S_1$** | 23.12 fg |
| **$P_0S_2$** | 23.33 fg |
| **$P_0S_3$** | 22.85 fg |
| **$P_1S_0$** | 22.75 g |
| **$P_1S_1$** | 26.45 de |
| **$P_1S_2$** | 27.50 cd |
| **$P_1S_3$** | 26.00 de |
| **$P_2S_0$** | 23.48 fg |
| **$P_2S_1$** | 22.67 g |
| **$P_2S_2$** | 30.75 a |
| **$P_2S_3$** | 30.00 ab |
| **$P_3S_0$** | 20.60 h |
| **$P_3S_1$** | 25.00 ef |
| **$P_3S_2$** | 28.50 bc |
| **$P_3S_3$** | 23.77 fg |
| **CV (%)** | **4.62%** |
| **SE** | **0.66** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

### 4.1.8 Grain yield (t $ha^{-1}$)

#### 4.1.8.1 Effect of phosphorus

Analysis of variance in data was presented in Appendix V where it was found that the grain yield of BRRI dhan56 was significantly influenced due to the different levels of phosphorus in this study (Table 7). From the Table 7, it was found that the grain yield due to various levels of phosphorus ranged from 3.77 to 5.12 t $ha^{-1}$. All the treatments showed higher grain yield over control (Table 7). The highest grain yield (5.12 t $ha^{-1}$) was found from $P_2$ (40 kg P $ha^{-1}$) which was statistically differed from other P levels. In contrast, the lowest grain yield (3.77 t $ha^{-1}$) was recorded in (control) $P_0$ which was also statistically differed from other P levels. The yield contributing characters like tiller production hill$^{-1}$, filled grains panicle$^{-1}$, 1000-grain yield were also found in 40 kg P ha$^{-1}$ treatment which probably contributed to obtained the higher grain yield in this treatment $P_2$ i.e. 40 kg P ha$^{-1}$. Similar findings were also obtained by Srivastava *et al*. (2014) on basmati rice with the effect of Zn and P levels. The highest grain yields of basmati rice were obtained with soil application of 17.5 kg P ha$^{-1}$. These results are also agreed with Rasavel *et al*. (2013) who also found that the highest grain yield (5216, 4678 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. Yosef (2013a) also reported that the maximum grain yield (4540) was observed for 90 kg ha$^{-1}$ phosphorus fertilizer and minimum of that was (3800) obtained for (control) 0 kg ha$^{-1}$ phosphorus fertilizer. Similarly Yose (2012) found that yield increased significantly with phosphorus fertilizer. Similar study were also obtained by Alam *et al*. (2009) in rice where they found that grain yield differed significantly with the application of P fertilizer while 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$^{-1}$).

#### 4.1.8.2 Effect of sulphur

Grain yield varied significantly due to different levels of sulphur where significant grain yield varied from 3.96 to 4.75 t ha$^{-1}$ (Appendix V and Table 8). The highest grain yield (4.75 t ha$^{-1}$) was recorded from $S_2$ (20 kg S ha$^{-1}$) which was statistically significant with other treatments and also over control. The lowest grain yield (3.96 t ha$^{-1}$) was recorded from $S_0$ (control) while it was statistically identical with $S_3$ (30 kg S ha$^{-1}$) (4.07 t ha$^{-1}$). On the basis of this investigation it was observed that the increasing levels of sulphur increased the grain yield up to 20 kg S ha$^{-1}$. Similar trend was also observed by Islam *et al*. (2009) who reported that the highest grain yield of 5293 kg ha$^{-1}$ was obtained from 16 kg S ha$^{-1}$ applied as gypsum. The lowest grain yield (4200 kg ha$^{-1}$) was recorded with S control treatment.

### 4.1.8.3 Interaction effect of phosphorus and sulphur

Significant variation was found due to the interaction effect of phosphorus and sulphur application (Appendix V and Table 9). From the Table 9, it was found that the grain yield varied from 3.50 to 5.64 t ha$^{-1}$ whereas the higher yield of grain was found from treatment combination of $P_2S_2$ (40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$) which was statistically significant different from other interactions. In contrast, interaction effect of $P_0S_0$ (0 kg P ha$^{-1}$ and 0 kg S ha$^{-1}$) recorded the lowest yield of grain (3.50 t ha$^{-1}$) which was closely followed by $P_0S_1$ and $P_0S_3$ (3.92 and 3.88 t ha$^{-1}$) (Table 9). These result revealed that treatment combination of $P_0S_0$ obtained the lower yield of rice due to its minimum tiller and effective tillers production, minimum filled grain and lower sizes grain were obtained under those treatments. Similarly, interaction effect of $P_2S_2$ (40 kg P ha$^{-1}$ and 20 kg S ha$^{-1}$) achieved highest grain yield due to its higher production of total and effective tillers hill$^{-1}$, maximum filled grains panicle$^{-1}$ and larger sizes grain of the studied rice cultivar.

### 4.1.9 Straw yield (t ha$^{-1}$)

### 4.1.9.1 Effect of phosphorus

Effect of various doses of phosphorus was significantly influenced on the production of straw of BRRI dhan56 in this study (Appendix V). The significant result of straw yield was also presented in Table 7 where the straw yield ranged from 7.05 to 8.39 t ha$^{-1}$ due to the phosphorus levels while all the phosphorus levels gave higher straw yield over control. The highest straw yield (8.39 t ha$^{-1}$) was found from treatment $P_2$ (40 kg P ha$^{-1}$) while $P_0$ (control) noticed the lowest straw yield (7.05 t ha$^{-1}$). The straw yield of 7.52 and 7.29 t ha$^{-1}$ were found from

$P_1$ and $P_3$ treatments, respectively. The results revealed that the application of 40 kg P $ha^{-1}$ ($P_2$) exerted pronounced effect in producing higher straw yields of BRRI dhan56. This might be due to the phosphorus increase strength of rice, prevent lodging and increase resistance to pest which ultimately results higher yield of straw. Beside, the variation in straw yield also might be due to the variation in plant height and tiller production which results were also similar to Rasavel and Ravichandran (2013) who found that the highest 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. Similarly, Alam *et al*. (2009) found that the straw yield differed significantly with the application of P fertilizer while phosphorus at 72 kg $ha^{-1}$ ($P_3$) produced the highest straw yield of rice.

#### 4.1.9.2 Effect of sulphur

Different levels of sulphur differed significantly on straw yield of T. *aman* rice (Appendix V and Table 8). The highest straw yield (8.08 t $ha^{-1}$) was recorded from $S_2$ treatment (20 kg S $ha^{-1}$) which was statistically significant from other S levels. In contrast, the lowest straw yield (7.18 t $ha^{-1}$) was recorded in $S_0$ (control) which was statistically identical with $S_3$ (30 kg S $ha^{-1}$) (7.29 t $ha^{-1}$). These result revealed that straw yield were more significant in 20 kg S $ha^{-1}$ and thereafter it decreased at 30 kg S $ha^{-1}$. Similarly, Islam *et al*. (2009) reported that the highest straw yield of 6380 kg $ha^{-1}$ was obtained from 16 kg S $ha^{-1}$ applied as gypsum and the lowest straw yield (4963 kg $ha^{-1}$) was recorded with S control treatment.

#### 4.1.9.3 Interaction effect of phosphorus and sulphur

Straw yield was significantly influenced by the interactions effect of phosphorus and sulphur fertilizers (Appendix V and Table 9). From the Table 9, it was found that the straw yield varied from 6.72 to 8.97 t $ha^{-1}$ due to the interaction treatments where the highest yield of straw (8.97 t $ha^{-1}$) was found in $P_2S_2$ (40 kg P and 20 kg S $ha^{-1}$) while the lowest yield of straw (6.72 t $ha^{-1}$) was recorded in interaction of control ($P_0S_0$) and it was closely followed by the interaction of $P_0S_3$ (0 kg P and 30 kg S $ha^{-1}$) (6.83 t $ha^{-1}$). These results revealed that both control fertilizers (without phosphorus and sulphur) were less efficient to produce straw yield in case of the shortest plant was achieved under this interaction. Besides, higher doses of phosphorus as soil or foliar application in combined with soil application of sulphur produced tallest plant and more tillers which ensure the higher straw yield in this study.

### 4.1.10 Biological yield (t $ha^{-1}$)

#### 4.1.10.1 Effect of phosphorus

Biological yield is a summation yield of grain and straw which was significantly affected by the application of different doses of phosphorus (Appendix V and Table 7). The highest biological yield (13.51 t $ha^{-1}$) was found from $P_2$ (40 kg P $ha^{-1}$) while the lowest biological yield (10.81 t $ha^{-1}$) was recorded in $P_0$ (control). So, the biological yield ranged was 10.81 to 13.51 t $ha^{-1}$ due to the phosphorus application in this study. The biological yield of 11.77 and 11.31 t $ha^{-1}$ were also found in $P_1$ (20 kg $ha^{-1}$) and $P_3$ (60 kg $ha^{-1}$), respectively. The results revealed that all the treatments were statistically significant with each other and 40 kg P $ha^{-1}$ obtained the highest biological yield because of the tallest plant and maximum total tillers were achieved under this P level. Yosef (2013b) also found significant variation in biological yield due to phosphorus application where they reported that maximum biological yield was (9120) that observed for 90 kg $ha^{-1}$ phosphorus fertilizer and minimum of these was (7638) obtained for (control) 0 kg $ha^{-1}$ phosphorus fertilizer. Similarly, significant variation in biological yield of rice was also reported by Rasavel *et al.* (2013), Yose (2012) and Alam *et al.* (2009).

#### 4.1.10.2 Effect of sulphur

A significant variation was found due to the effect of sulphur application in respect of biological yield (Appendix V and Table 8). From the Table 8, it was found that the biological yield was higher (12.82 t $ha^{-1}$) in $S_2$ (20 kg S $ha^{-1}$) than that of other S levels and also over $S_0$ (control). However, it was closely followed by $S_1$ (10 kg S $ha^{-1}$) (12.09 t $ha^{-1}$). Similarly, the lowest biological yield (11.14 t $ha^{-1}$) was observed in $S_0$ (control) while $S_3$ (30 kg S $ha^{-1}$) produced statistically similar lower biological yield (11.36 t $ha^{-1}$). The variation result on biological yield was found due to the variation in sulphur which result supported by Khan *et al.* (2012) where they found that significant increase in biological and paddy was recorded with foliar $KNO_3$ @ 1.5% and 2% over soil applied $K_2SO_4$.

#### 4.1.10.3 Interaction effect of phosphorus and sulphur

Biological yield was also significantly influenced for the interactions effect of phosphorus and sulphur fertilizer (Appendix V and Table 9). Result showed that significantly the highest biological yield (14.61 t $ha^{-1}$) was obtained from the interaction effect of $P_2S_2$ (40 kg P and 20 kg S $ha^{-1}$) which was statistically differed from other interactions. Similarly, the lowest biological yield (10.22 t $ha^{-1}$) was recorded in interaction of both $P_0S_0$ (control) which was closely followed by $P_0S_3$ (10.44 t $ha^{-1}$) and $P_4S_0$ (10.60 t $ha^{-1}$) but they were not statistically identical. These result revealed that the treatment combination of 40 kg P $ha^{-1}$ × 20 kg S $ha^{-1}$ recorded the maximum biological yield in case of the higher grain and straw yield were obtained in those treatments.

### 4.1.11 Harvest index (%)

#### 4.1.11.1 Main effect of phosphorus

Application of phosphorus at various levels showed significant variation in respect of harvest index in the present study (Appendix V and Table 7). From the Table 7, it was appeared that the highest harvest index (37.85%) was found in $P_2$ (40 kg P $ha^{-1}$) because of the highest portion of grain yield and straw as well as maximum biological yield were found under this treatment. Similarly, the $P_0$ (control treatment) observed the lowest harvest index (34.82%) due to its lowest yield of grain and straw as well as minimum biological yield were achieved in this treatment. Another treatment also showed significant effect while harvest index of 36.03 and 35.47% were found in $P_1$ and $P_3$, respectively (Table 7). These results revealed that the variation in harvest index was found due the variation in phosphorus levels. These were similar to Yosef (2013b) whereas they found that the maximum harvest index was (47.92) observed for 90 kg $ha^{-1}$ phosphorus fertilizer and minimum of that was (47.79) obtained for (control) 0 kg $ha^{-1}$ phosphorus fertilizer.

**Table 7. Effect of phosphorus on yield characters and HI at harvest**

| Phosphorus levels (kg $ha^{-1}$) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| **$P_0$** | 3.77 d | 7.05 d | 10.82 d | 34.82 c |
| **$P_1$** | 4.25 b | 7.52 b | 11.77 b | 36.03 b |
| **$P_2$** | 5.12 a | 8.39 a | 13.51 a | 37.85 a |
| **$P_3$** | 4.02 c | 7.29 c | 11.31 c | 35.47 bc |
| **CV (%)** | **1.65** | **1.26** | **2.65** | **2.36** |
| **SE** | **0.20** | **0.027** | **0.09** | **0.25** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

### 4.1.11.2 Effect of sulphur

Harvest index represent comparative yield performance between grain and straw yield. It also indicates the percent grain yield on the basis of biological yield. The data on harvest index was significantly influenced by the sulphur application in this study (Appendix V). Treatment $S_2$ (20 kg S $ha^{-1}$) recorded the highest harvest index (36.90%). The lowest harvest index (35.45%) was observed in $S_0$ (control) which was statistically similar to $S_3$ (30 kg S ha$^{-1}$) (35.71%). However, treatment $S_1$ (10 kg S ha$^{-1}$) obtained harvest index of 36.11% which was close to both higher and lower harvest index in this study (Table 8). These results revealed that harvest index differed significantly due to the significant differences of the studied sulphur application and also the variation of grain and straw yield as well as biological yield.

**Table 8. Effect of sulphur on yield characters and HI at harvest**

| Sulphur levels (kg ha$^{-1}$) | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| **$S_0$** | 3.96 c | 7.18 c | 11.14 b | 35.45 b |
| **$S_1$** | 4.38 b | 7.71 b | 12.09 ab | 36.11 ab |
| **$S_2$** | 4.75 a | 8.08 a | 12.83 a | 36.90 a |
| **$S_3$** | 4.07 c | 7.29 c | 11.36 b | 35.71 b |
| **CV (%)** | **1.65** | **1.26** | **2.65** | **2.36** |
| **SE** | **0.05** | **0.08** | **0.4** | **0.24** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; *= Significant at 5% level of probability

### 4.1.12.3 Interaction effect of phosphorus and sulphur

Analysis of variance data regarding to harvest index was significantly influenced by the interaction effect of phosphorus and sulphur fertilizers (Appendix V and Table 9). Table 9 indicated that the harvest index varied from 34.24 to 38.59% where the interaction treatment of $P_2S_2$ (40 kg P and 20 kg S ha$^{-1}$) recorded the highest harvest index (38.59%) which was closely followed by the interactions effect of $P_3S_1$ (37.83%), $P_1S_2$ (37.18%), $P_2S_0$ (37.39%) and $P_2S_3$ (37.58%) whereas $P_1S_2$, $P_2S_0$ and $P_2S_3$ were statistically identical. In contrast, the lowest harvest index (34.24%) was recorded in $P_0S_0$ (control) which was also closely followed by the maximum interactions of both fertilizers among the rest interaction effects. The variation in harvest index was found due to the variation yield of grain, straw and biological yield and also the variation in fertilizer levels.

**Table 9. Interaction effect of phosphorus and sulphur on yield characters and HI at harvest**

| Treatment combinations | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| $P_0S_0$ | 3.50 k | 6.72 l | 10.22 l | 34.24 f |
| $P_0S_1$ | 3.91 gh | 7.25 gh | 11.17 ghij | 35.05 def |
| $P_0S_2$ | 4.05 f | 7.39 fg | 11.44 fgh | 35.44 def |
| $P_0S_3$ | 3.61 jk | 6.83 kl | 10.44 kl | 34.55 ef |
| $P_1S_0$ | 3.88 gh | 7.09 hi | 10.97 hijk | 35.33 def |
| $P_1S_1$ | 4.29 e | 7.63 e | 11.92 ef | 36.00 cde |
| $P_1S_2$ | 4.83 c | 8.16 c | 12.99 c | 37.18 abc |
| $P_1S_3$ | 3.99 fg | 7.21 h | 11.20 ghi | 35.60 def |
| $P_2S_0$ | 4.77 c | 7.98 d | 12.76 cd | 37.39 abc |
| $P_2S_1$ | 5.19 b | 8.52 b | 13.71 b | 37.83 ab |
| $P_2S_2$ | 5.64 a | 8.97 a | 14.61 a | 38.59 a |
| $P_2S_3$ | 4.88 c | 8.10 cd | 12.98 c | 37.58 abc |
| $P_3S_0$ | 3.69 ij | 6.91 jk | 10.60 jkl | 34.83 def |
| $P_3S_1$ | 4.11 f | 7.45 f | 11.56 fg | 35.56 def |
| $P_3S_2$ | 4.46 d | 7.79 e | 12.24 de | 36.39 bcd |
| $P_3S_3$ | 3.80 hi | 7.03 ij | 10.83 ijk | 35.11 def |
| **CV (%)** | **1.65** | **1.26** | **2.65** | **2.36** |
| **SE** | **0.04** | **0.05** | **0.18** | **0.49** |

Figures followed by same letter(s) are statistically similar as per DMRT at 5%
CV= Co–efficient of variation; SE= Standard error

## CHAPTER V

## SUMMARY AND CONCLUSION

The present experiment was conducted at the Research Field of the Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from July 2013 to December 2013 to evaluate the performance of BRRI dhan56 in respect of growth and yield under the AEZ-28. The rice variety cv. BRRI dhan56 was used as planting materials for the present study which was collected from BRRI, Joydebpur, Gazipur. The two factors experiment consists with four levels of phosphorus (P) *viz.* $P_0$: without phosphorus (control), $P_1$: 20 kg $ha^{-1}$, $P_2$: 40 kg $ha^{-1}$ and $P_3$: 60 kg $ha^{-1}$ and four levels of sulphur *viz.* $S_0$: without sulphur (control), $S_1$: 10 kg $ha^{-1}$, $S_2$: 20 kg $ha^{-1}$ and $S_3$: 30 kg $ha^{-1}$. The experiment was laid out in Randomized Completele Block Design (RCBD) method with three replications and analysis was done by the MSTAT-C package program whereas means were adjudged by DMRT at 5% level of probability.

The results of the present study were obtained on various characteristics of growth, yield and yield attributing traits of BRRI dhan56 whereas all the studied characters were statistically significant at 5% level due to phosphorus application where 40 kg P $ha^{-1}$ showed superior performance on them. The result of plant height and tillers $hill^{-1}$ were increased significantly throughout the growth period while tillers production significantly decreased at harvest due to its mortality during maturity. As a result, the tallest plant (109.70 cm) was found in treatment $P_2$ (40 kg P $ha^{-1}$) while $P_0$ (control) recorded the shortest plant (102.20 cm) at harvest. Similarly, maximum tillers $hill^{-1}$ (15.99) was obtained in $P_2$ (40 kg P $ha^{-1}$) and $P_0$ (control) obtained the minimum tillers $hill^{-1}$ (11.01) at harvest. Treatment $P_2$ (40 kg P $ha^{-1}$) also recorded the greater results on effective tillers $hill^{-1}$ (13.67), filled grains $panicle^{-1}$ (138.60), 1000-grain weight (26.73 g), yield of grain, straw and biological (5.12, 8.39 and 13.51 t $ha^{-1}$, respectively) and harvest index (37.85%) at harvest while $P_0$

(control) obtained the lower results on the above parameters (7.98, 110.0, 22.83 g, 3.77 t $ha^{-1}$, 7.05 t $ha^{-1}$, 10.82 t $ha^{-1}$ and 34.82%, respectively) whereas all the treatments of P were statistically differed with each other. However, $P_2$ (40 kg P $ha^{-1}$) noticed the minimum non effective tillers $hill^{-1}$ (2.33) and unfilled grains $panicle^{-1}$ (8.45) and $P_0$ (control) treatment obtained the maximum non effective tillers $hill^{-1}$ (3.85) and unfilled grains $panicle^{-1}$ (15.93).

All the above mentioned characters were also significantly influenced by sulphur application. However, plant height at 55 DAT and filled grains $panicle^{-1}$ did not vary significantly due to the effect of S. The data on plant height and tillers $hill^{-1}$ were recorded at 30 days interval from 25 DAT to 85 DAT and at harvest where plant height increased up to harvest and tiller production at 85 DAT and decreased at harvest due to mortality. However, treatment $S_2$ (20 kg S $ha^{-1}$) obtained the tallest plant (109.40 cm) at harvest while treatment $S_0$ (control) recorded the shortest plant (103.20 cm) at harvest. Maximum tillers $hill^{-1}$ (14.75) was also observed in $S_2$ (20 kg S $ha^{-1}$) and minimum tillers $hill^{-1}$ (11.98) in $S_0$ (control) at harvest. On the other hand, the maximum effective tillers $hill^{-1}$ (12.12), 1000-grain weight (27.52 g), yield of grain, straw and biological (4.75, 8.08 and 12.83 t $ha^{-1}$, respectively) and harvest index (36.90%) were observed in $S_2$ (20 kg S $ha^{-1}$) at harvest. Similarly, $S_0$ (control) recorded the minimum effective tillers $hill^{-1}$ (9.37), minimum yield of grain, straw and biological (3.96, 7.18 and 11.14 t $ha^{-1}$, respectively) and lowest HI (35.45%) whereas statistically similar lower effective tillers $hill^{-1}$ (9.47), lowest yield of grain, straw and biological (4.07, 7.29 and 11.36 t $ha^{-1}$, respectively) and lowest HI (35.71%) were also found in higher doses of $S_3$ (30 kg S $ha^{-1}$). However, 20 kg S $ha^{-1}$ observed the minimum non effective tillers $hill^{-1}$ (2.83) and unfilled grains $panicle^{-1}$ (12.04) but maximum non effective tillers hill (3.38) and unfilled grains $panicle^{-1}$ (13.42) were taken in $S_3$ (30 kg S $ha^{-1}$) and $S_1$ (10 kg S $ha^{-1}$), respectively.

All the studied characters among the growth, yield and yield contributing were significantly affected by the interaction effect of phosphorus and sulphur fertilizers at all the growth stages and at harvest whereas the combination of $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) performed best comparatively than that of other combinations. However, number of tillers $hill^{-1}$ increased with the advancement of time but decreased at harvest. As a result, the maximum tillers $hill^{-1}$ (17.50) was obtained from the combination of $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) while minimum tillers $hill^{-1}$ (9.59) was found from $P_0S_0$ (without P and S). Plant height was also highest (111.60 cm) in $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) and the lowest (95.65 cm) in $P_0S_0$ (without P and S) at harvest. The interaction effect of $P_2S_2$ (40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$) also produced maximum effective (15.53) and minimum non effective tillers $hill^{-1}$ (1.97), maximum filled (141.40) and minimum unfilled grains $panicle^{-1}$ (7.87), highest 1000-grain weight (30.75 g), highest yield of grain, straw and biological (5.64, 8.97 and 14.61 t $ha^{-1}$) and higher HI (38.59%) whereas they were statistically significant among other interactions in respect of all the above traits. However, interaction of $P_0S_0$ (without P and S) recorded the minimum effective tillers $hill^{-1}$ (7.17), minimum filled grains $panicle^{-1}$ (108.80), lowest grain, straw and biological yield (3.50, 6.72 and10.22 t $ha^{-1}$) and lowest HI (34.24%), respectively. Number of non effective tillers $hill^{-1}$ and unfilled grains $panicle^{-1}$ had maximum (3.97 and 16.27, respectively) in $P_0S_3$ and $P_0S_1$, respectively at harvest which was statistically differed from other interactions.

From the above results, it could be concluded that 40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$ singly or their interaction showed the superior performance concerning to growth, yield and yield traits of BRRI dhan56 in this study. As a result, the tallest plant, maximum total and effective tillers, maximum filled grain, the highest 1000-grain weight, highest grain, straw and biological yield as well as highest HI were taken by the single or interaction of 40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$ compare to that of other studied treatments. Finally, it could be concluded and recommended that the use of 40 kg P $ha^{-1}$ and 20 kg S $ha^{-1}$ as singly or their interaction would be highly effective for higher production of BRRI dhan56 under the regional condition of AEZ–28. Further study may be needed for ensuring the performance of the present study in different AEZ of Bangladesh.

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# APPENDICES

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

### Morphological characteristics

| Constituents | Characteristics |
|---|---|
| Location | Field Laboratory, Department of Soil Science, SAU, Dhaka |
| Soil Series | Tejgaon |
| Soil Tract | Modhupur |
| Land type | High |
| General soil type | Deep Red Brown Terrace Soil |
| Agro-Ecological Zone | “AEZ-28” |
| Topography | Fairly level |
| Soil type and colour | Deep Red Brown Terrace Soil |
| Drainage | Moderate |
| Depth of inundation | Above the flood level |
| Drainage condition | Well drained |

### Physical properties of the soil

| Constituents | Results |
|---|---|
| Particle size analysis | 2.57 |
| Bulk density (g/cc) | 1.42 |
| Porosity (%) | 44.7 |
| Sand (%) (>0.02 mm) | 21.75 |
| Silt (1%) (0.02-0.002 mm) | 66.60 |

| | |
|---|---|
| Clay (%) (<0.002 mm) | 11.65 |
| Soil textural class | Silty loam |
| Color | Dark grey |
| Consistency | Grounder |

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

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

| **Constituents** | **Results** |
|---|---|
| Soil pH | 5.8 |
| Organic matter (%) | 1.30 |
| Total nitrogen (%) | 0.101 |
| Available phosphorus (ppm) | 27 |
| Exchangeable potassium (meq/100 g soil) | 0.12 |
| Available Sulphur (ppm) | 22.7 |

**Methods of analysis**

| **Texture** | **Hydrometer methods** |
|---|---|
| pH | Ptentiometric method |
| Organic carbon | Walkely-Black method |
| Total N | Modified kjeldhal method |
| Available P | Olsen method ($NAHCO^3$) |
| Exchangeable K | Flame photometer method |
| Available S | Spectrophotometer methods (0.15% $CaCl_2$ solution) |

Result obtained from the chemical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

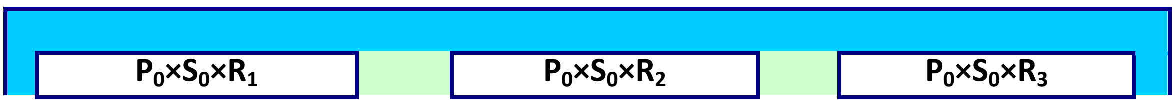
**Appendix II. Monthly air temperature, rainfall, relative humidity and sunshine hours during the growing season (July to December 2013)**

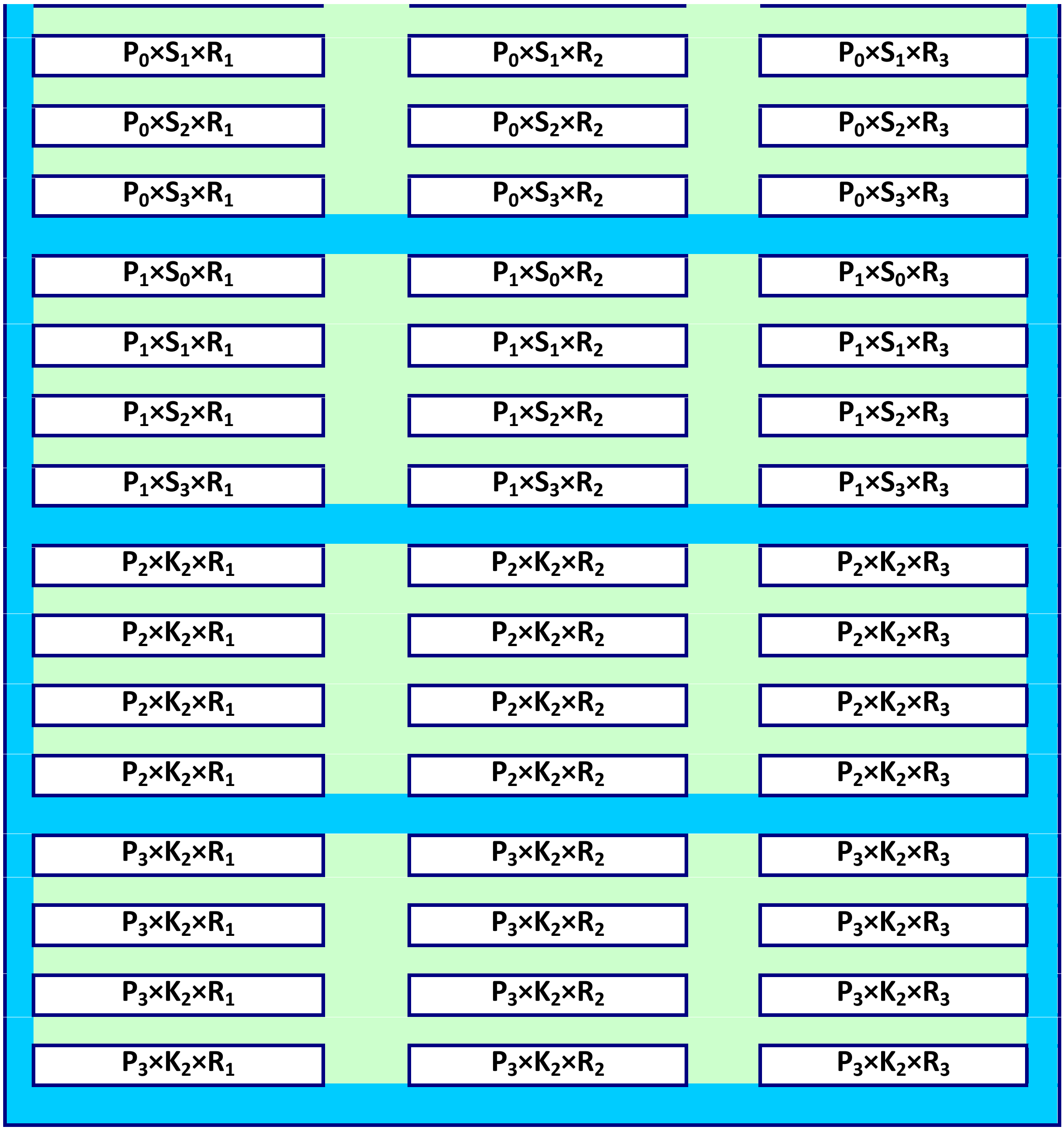
| Month | *Air temperature ($^{O}C$) | | | **Rainfall (mm) | *Relative humidity (%) | ** Sunshine (hrs) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | | | |
| July | 28.77 | 15.33 | 22.05 | 0 | 73.57 | 223.40 |
| August | 30.93 | 18.95 | 24.94 | 18.1 | 75.16 | 202.10 |
| September | 28.53 | 16.85 | 22.69 | 19.58 | 79.58 | 119.65 |
| October | 27.15 | 15.99 | 21.57 | 23.21 | 81.62 | 101.41 |
| November | 26.54 | 14.61 | 20.58 | 21.54 | 82.35 | 111.26 |
| December | 24.92 | 13.46 | 19.19 | 0 | 86.16 | 160.40 |

* Monthly average and ** Monthly total

**Source:** Bangladesh Meteorological Department (Climate division), Dhaka.

**Appendix III: Lay out of the experiment**






**Legend:**

Treatments: 16 (P: 4 × S: 4); Replication: 3 (Three); Number of plot: 48

Length of plot: 4.0 m; Width of a plot: 3.0 m; Area of a plot: 12.0 $m^2$

Row to row distance: 0.20 m; plant to plant distance: 0.20 cm

**Appendix IV. Analysis of variance (mean square) for tiller production (no.) and grain production (no.) at harvest**

| Source of variation | Degrees of freedom | No. of non effective tillers hill$^{-1}$ | No. of effective tillers hill$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ |
|---|---|---|---|---|---|
| Replication | 2 | 1.063 | 0.056 | 393.547 | 7.472 |
| Phosphorus (A) | 3 | 70.915** | 4.886** | 1784.197** | 121.404** |
| Error | 6 | 0.104 | 0.006 | 65.631 | 1.674 |
| Sulphur (B) | 3 | 19.673** | 0.721** | 156.657ns | 4.367* |
| A×B | 9 | 0.031* | 0.031** | 13.205** | 0.395** |
| Error | 24 | 0.011 | 0.001 | 1.373 | 0.087 |

**Appendix V. Analysis of variance (mean square) for different yield and yield contributing characters of rice cv. BRRI dhan56**

| Source of variation | Degrees of freedom | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|
| Replication | 2 | 0.189 | 0.771 | 7.877 | 20.901 |
| Phosphorus (A) | 3 | 4.131** | 4.117** | 16.55** | 20.29** |
| Error | 6 | 0.034 | 0.078 | 1.877 | 0.708 |

| | | | | | |
|---|---|---|---|---|---|
| Sulphur (B) | 3 | 1.494** | 2.027** | 6.957* | 4.827* |
| A×B | 9 | 0.022** | 0.022* | 0.088* | 0.083* |
| Error | 24 | 0.005 | 0.009 | 0.098 | 0.723 |

*= Significant at 5% level of probability and ns= not significant