DIRECT AND RESIDUAL EFFECTS OF PHOSPHATE ROCK ON SOIL NUTRIENT STATUS AND CROP PRODUCTIVITY IN RICE-RICE CROPPING SEQUENCE

JANNATUL FIRDOUSI

DEPARTMENT OF SOIL SCIENCE SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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By

JANNATUL FIRDOUSI

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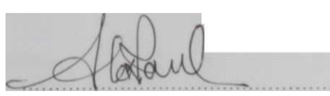
Approved By:

Supervisor
Dr. Gopi Nath Chandra Sutradhar
Associate professor
Department of Soil Science
Sher-e-Bangla Agricultural University.
Dhaka

Co- supervisor
Dr. G.K.M. Mustafizur Rahman
Associate Professor
Chairman, Department of Soil Science
Bangladesh Sheikh Mujibur Rahman Agricultural University (BSMRAU),
Shalna, Gazipur



Chairman
Dr. Alok Kumar Paul
Department of Soil Science Sher-e-Bangla Agricultural University, Dhaka

CERTIFICATE

This is to certify that thesis entitled**, "DISTRICT AND RESIDUAL EFFECTS OF PHOSPHATE ROCK ON SOIL NUTRIENT STATUS AND CROP PRODUCTIVITY IN RICE-RICE CROPPING SEQUENCE"** Submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of ***M IS'TER OF SCIENCE (M.S.)* in *SOIL* SCIENCE** embodies the result of a piece of *bona fide* research work carried out by ***jannatul Ferdous*** **Registration No 25270/00376** under my supervision and guidance No part of the thesis has been submitted for any other degree or diploma.

1 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 her

Dated

Place: Dhaka, Bangladesh

Supervisor

Dr. Gopi Nath Chandra Sutradha

DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

Two field experiments were conducted in the same plot in rice-rice cropping sequence during 2005 at sher-e-Bangla Agricultural University farm under Madhupur tract (AEZ-28), to study the direct and residual effects of rock phosphate (PR) as compared to TSP on growth, yield and nutrient uptake of Boro rice (BR-29) as first crop and T.aman (BR-30) as residual crop. The experiments were laid out in a Randomized Complete Block Design (RCBD) with five treatments and four replications of each treatment. The treatments used were T_r control (0 kg P ha$^{'1}$), T_2-PR (35 kg P ha$^{'1}$), T_3-TSP (35 kg P ha^{1}), T_4-PR (210 kg P ha$^{'1}$, applied in the previous crop in 2004) and T_5-TSP (17.5 kg P ha$^{'1}$) + PR (17.5 kg P ha$^{'1}$). The blanket application of recommended doses of N, P, K, S, and Zn was done in all the treatments. In case the first crop, application of full dose of P (35 kg P ha$^{'1}$) as TSP (T_3) and 1:1 mixture of TSP (17.5 kg P ha$^{'1}$) and PR (17.5 kg P ha$^{'1}$) (T_5) increased dry matter production at panicle initiation stage, grain and straw yield at the harvest over the control. The highest grain yield (6.8 t ha^{1}) and straw yield (7.47 t ha$^{'1}$) were obtained in the treatment T_5 where a judicious mixture of PR and TSP was used. Application of full does of P as PR and 210 kg P applied in the previous crop had no significant effects on yield of rice. The grain yield due to different treatment ranked in the order of $T_5 > T_3 > T_2 > T_4 >$ T|. In general these treatments (T_3 and T_5) increased effective tiller hill$^{'1}$, filled grains panicle$^{'1}$ and N, P, K. and S uptake significantly. In case of residual crop, the treatment T_3 and T_5 had a significant residual effect regarding grain yield and P uptake. The residual effect of the treatment T_5 produced the highest grain yield (4.5 t ha$^{'1}$). After the harvest of two crops in all P treatments, the soil contained significantly higher amount of organic matter, available sulpher. available P and exchangeable K as compared to the control. The treatments had no significant effect on soil PH and total nitrogen content.

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Chapter I

INTRODUCTION

Rice (*Oryze saliva)* is the staple food of Bangladesh. It constitutes 95% of the cereals consumed in our country and contributes 68% of the calories and 54% of the protein intake for the average diet of people (Rashid ,1994). Rice is grown in Aus, Aman and Boro seasons in Bangladesh. Geographical situation as well as the climatic and edaphic conditions of Bangladesh are favourable for year-round rice cultivation. About 75% of the total cropped area of Bangladesh is devoted to rice production with the area and production being 10.8 million hectares and 25.2 million tons, respectively (BBS, 2004). About 32% of the area and 48% of the rice production are covered by boro rice alone (BBS, 2002).

Rice is the first cereal crop of Bangladesh. Increased rice production in this country is essential to meet the food demand of the teeming population. Bangladesh ranks 4"' both in respect of area and production of rice among the rice producing countries following China, India and Indonesia (FAO, 1994) but ranks 39^{,h} in respect of average yield (IRRI, 1995). The average yield is only 2.33 t ha$^{'1}$ (BBS, 2004), which is much lower than the world average (2.9 t ha$^{'1}$) and frustratingly lower than the highest average yield (6.1 t ha^{1}) as demonstrated in South Korea (Swaminathan, 1997). Comparatively lower yield of rice in Bangladesh may be attributed to lack of improved varieties and proper nutrient management.

Phosphorus is the second key nutrient element (next to nitrogen) needed in adequate quantity in available forms for successful crop production. Phosphorus is indispensable for all forms of life because of its genetic role in nucleic acids and function in energy transfers via ATP (Ozanne, 1980). It is associated with several vital functions and is responsible for typical characteristics of plant growth involved in biochemical functions such as utilization of sugar, starch, polysaccharides, nucleic acid formation, cell organization and the transfer of hereditary characters (Brady, 1989). Phosphorus docs not occur abundantly in soils as N and K. Total content of P in surface soil varies between 0.02 and 0.10% (Tisdale *et al.*, 1997). P docs not readily leach and fertilizer P therefore largely remains in the soil.

The phosphorus content of Bangladesh soils is being depleted day by day due to crop removal particularly in intensive cropping with high yielding varieties, low use of organic matter and improper soil and crop management practices (Ali *et al.*, 1997). In soil, phosphorus is present both organic and inorganic forms but main problem concerning I* fertilizer is its fixation with soil constituents within short period of application rendering more than two-thirds unavailable (Mandal and Khan, 1972). Immediate conversion of the water soluble P, due to P fixation, results in low fertilizer use efficiency (Biswas *et al.* 1998). Deficiency of phosphorus is widespread in Bangladesh soils. The soils deficient in I*, cover roughly an area of 5.6 million hectares having pi I < 5.5 which arc mainly Latosols known for P fixation. Adequate P fertilization is thus essential for economic and sustained crop production on soils. The P-deficient soils require heavy dose of phosphatic fertilizers which are mostly imported and expensive as well.

Triple superphosphate (TSP) is the main fertilizer source of phosphorus, Single Superphosphate (SSP) is another water soluble P fertilizer and very recently Diammonium phosphate (DAP) and mono-ammonium phosphate (MAP) have been introduced phosphatic fertilizers in Bangladesh and their popularity is increasing day by day.

Phosphate rock (PR) is another source of phosphorus. It may also be mentioned here that TSP is being produced in Bangladesh, in a limited scale using imported phosphate rock (PR) with production capacity of 1,52,000 metric tons annually. It can meet only 25% of the total phosphorus fertilizer requirement of the country. One of the potential advantages of using reactive phosphate rock (RPR) as a phosphorus (P) fertilizer for improved crops / pastures is that RPR is a cheaper P fertilizer per kg of applied P than traditional water-soluble P (WSP) fertilizer such as superphosphate (SP) (Simpson *et al.* 1997).

Phosphate Rock (PR) is acidulated to manufacture SSP and TSP. For this reason TSP and SSP are costly materials. On the other hand powdered phosphate rock can be applied directly in the field. Phosphate rock (PR) is the cheapest and economic source of phosphorus (Hoffland, 1991). However it is not being used in the crop field due to its insolubility. Evaluation of the agronomic effectiveness PR relative to

SP is usually based on the concept the substitution value of the fertilizers (Barrow, 1990). It is possible to compare the effectiveness of PR and SP only by applying several levels of each fertilizer to a P-deficient soil, so that the relationship between plant yield and the level of P applied can be adequately defined (Parmer *et al.* 1988). It is considered as a promising source of P for acid soil specially red one. Considering the need of phosphatic fertilizer application, the high cost of the conventional water soluble P fertilizers constraints their use by our resource poor farmers.

The direct application of phosphate rock as a source of phosphorus has been found effective in acidic and P fixing soils especially for long duration crops (Mitra *et al.* 1992). Phosphate rock is a source not only of phosphorus, but also of other essential nutrients like calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), copper (Cu), and zinc (Zn) (Dev, 1990). Therefore, in the long term, the use of PR with a neutralizing value on acid soils offers the maximum possible scope for soil P fertility management. In addition, long term experiment suggest that continuous application of phosphate rock has a better residual effect than superphosphate (Thogbai *etal.* 1987; Balasubramaniyan, 1989). Finally, the cost- benefit ratio with the direct application of phosphate rock was found higher than that with other sources of P for growing rice (Policegoudar *etal.* 1994).

Phosphate rock has not been used commercially for crop production in Bangladesh. Phosphate rock (PR) is agronomically effective as well as less costly and highly profitable than TSP and SSP fertilizer (Goh and chews, 1995). Thus the use of PR may open a new horizon and become a commercially beneficial fertilizer for the farmers in Bangladesh . From this view point, the present experiment is designed to investigate the influence of direct application of phosphate rock and its residual effect on soil fertility and yield in rice-rice cropping sequence.

Objectives of the Research Project:

1. **To determine the response of PR to upland high yielding variety of rice (BRRI Dhan-29).**
2. **To compare the relative efficiency of PR with TSP as a source of P for rice.**
3. **To study of the residual effect of P in soil on succeeding rice crop (BRRI Dhan-30).**
4. **To study the effect of different source of phosphorus on N, P, K and S status of soil and their uptake by rice.**

Chapter II

REVIEW OF LITERATURE

Growth and development of rice plant are greatly influenced by the environmental factors, variety and cultural practices. Among these factors, fertilizers (especially phosphatic fertilizers like TSP, SSP, and PR etc.) play notable role regarding the growth and development of rice plants. A good number of research works have been conducted at home and abroad on the effect of phosphatic fertilizer on rice cultivation. Rock phosphate (PR) is more or less unknown as a fertilizer phosphorus to the farmers in producing crops in Bangladesh. Rock phosphate is the raw material for the manufacture of TSP and SSP fertilizers. Although an extensive research have been carried out in the world on rock phosphate as a phosphorus fertilizer, yet the work on comparative performance of rock phosphate with commonly used fertilizers such as TSP, SSP DAP etc. is very limited particularly under Bangladesh situation. In this chapter an attempt is made to review the available literature pertaining to the present study.

2.1 Influence of rock phosphate on crop yield

Most of the research reports showed a positive effect of the application of rock phosphate son yield of rice and other crops. The findings of various author are cited below:

Issak (2005) carried out a field experiment to study the influenced of rock phosphate (PR) in comparison to TSP as a source of P growth and yield of the rice crop. The results indicated that the grain yield increased due to the mixed application of rock phosphate (PR) and Triple Super Phosphate (TSP).

Islam (2005) carried out an experiment to study the effect of direct application of rock phosphate (PR) in comparison to TSP as a source of P. The results showed that the application of PR (210 kg P ha^{-1}) increased rice yield.

Rahman (2005) conducted two experiments in two different regions, one at BIN A sub-station, Comilla and another at BRRI sub-station, Rajshahi to study the effect of different treatments of PR and TSP on growth and yield of rice. Rice yield significantly increased due to higher rate of application of PR (210 kg P/ha) compared to other treatments.

Sharma *et al.* (2003) carried out a field experiment to study the phosphate efficiency of diammonium phosphate (DAP) and mussoorie rock phosphate (MRP) in combination with Phosphate Solubilizing Bacteria and crop residues incorporation in rice-wheat cropping system. It increased grain and straw yields as well as P uptake of both rice and wheat. The result indicated that low grade rock phosphate such as MRP can be advantageously utilized in rice-wheat cropping system w hen applied with PSB inoculation and incorporation of rice and wheat residues.

Kumar *et al.* (2002) conducted a two years field experiments to evaluate P sources for meeting partial P demand and economizing the P fertilizer input of the rice based cropping system. Two sources of P viz. single superphosphate (SSP) and Mussoorie rock phosphate (MPR) applied at four levels (0. 30. 60 and 90 kg P ha) were tested in kharif rice and succeeding blackgram (rabi). The response to graded P application through different sources was computed by fitting response curves which indicated lower dose of P input (64.16 kg ha^{-1}) through MPR source compared to SSP (73.64 kg ha^{-1}) for obtaining maximum rice equivalent yields of the system. The suggested that mussoorie rock phosphate can effectively be utilized as a source of P to rice-blackgram crop sequence as it recorded on par rice equivalent yields and gross returns compared to SSP.

Ravi *et al.* (2001) conducted a field experiment consisting of 15 treatments with three replications, which included water soluble sources like single superphosphate (SSP) and monoammonium phosphate (MAP), insoluble sources like maton rock phosphate (MRP), gafsaphos, North Carolina rock phosphate (NCRP), Jordan rock phosphate JPR (A) and JPR (B) and combination of JPR (A) or (B) with SSP, MAP and MAP + S. Results showed that the grain yield and P uptake by both main and residual crop during the first and second year were maximum with non combined JPR (A).

In a field experiment Sharma *et al.* (2001) investigated the effect of incorporation of wheat *(Triticum aestivum)* and rice (*Oryza saliva)* residue on the relative efficiency of diammonium phosphate and mussoorie rock phosphate in rice (cv. Pusa 169) wheat (cv. HD 2329) cropping system and found that incorporation of wheat residue before rice transplanting resulted in an increase in the efficiency of mussoorie rock phosphate. In rice residue incorporation, mussoorie rock phosphate increased grain yield of wheat.

Somado *et al.* (2001) reported the effect of rock phosphate (PR) combined with a pre-rice green manure (GM) on rice yield. Grain yield increase averaged over GM was 1.6 fold (PR) and two-fold with triple superphosphate (TSP) above the no-P control treatments.

Tomita *et al.* (2001) conducted a two year experiment to study the effect of phosphate rock at 0, 50, 100, 200 and 400 kg P_20_5 $ha^{'1}$ on rice cv. Panama-1048. The data showed maximum rice yields with phosphate rock at 400 kg P_2O_5 ha^{-1} compared with lime and TSP application.

Sankhajit *et al.* (2000) conducted a field experiment to study the effects of rock phosphate (60, 100 and 150 kg P ha ') and superphosphate (60 kg P ha^{-1}) on the nutrient content and yield of rice. Variations in crop yield due to PR or superphosphate application were not significant.

Ortega and Rojas (1999) found that SSP, TSP or rock phosphate generally increased grain yield and decreased floret sterility, with no effect of source, P availability was increased by P application.

Rajendran (1999) conducted two field experiments at Coimbatore, Tamilnadu. to study the effect of different sources and levels of phosphorus on growth and yield of hybrid rice cv. ADTRH 1. Mean grain yield was 4.34 t ha^{-1} without applied P, 5.4S- 5.73 t ha^{-1} with different sources of 60 kg P_2O_5 ha^{-1}. The highest yield was given by rock phosphate, although there was no statistically significant difference from P applied as superphosphate.

Rosamalin *et al.* (1999) conducted an experiment where the phosphate fertilizers used were rock phosphate (PR) in combination with TSP with or without liming. The treatments combination were PR 100%, PR 75% + TSP 25%, PR 50% - TSP 50%, PR 25% + TSP 75% and TSP 100%. The results showed that when lime was applied, TSP gave higher paddy grain yield compared to PR. In case of no liming. PR gave significantly higher yield compared to TSP.

Sahu *et al.* (1999) carried out an experiment on a rice-groundnut rotation, the first crop was given 40 or 80 kg P_2O_5 ha^{-1} as raw or acidulated rock phosphate (25 or

50%), single super phosphate (SSP) or raw rockphosphate + SSP. In the treatment where 40 kg P was applied to the first crop, the second crop was also given 40 kg P. they observed that the rice grain yield was the highest with 80 kg SSP and rock phosphate + SSP, while groundnut yield was the highest with 80 kg raw rock phosphate.

Bado and Hien (1998) conducted a comparative experiment on the agronomic efficiency of Burkina Faso rock phosphate (BPR) and TSP on upland rice with annual phosphate input levels of 0, 13, 26 and 39 kg P ha'^{1}. Results showed that application of TSP or BPR increased P absorption and rice yield.

Mongia *et al.* (1998) carried out a greenhouse experiment and showed that lime and rock phosphate application increased grain and straw yield of rice. The response of rice to P was more as compared to lime.

Rajkhowa and Baroova (1998) conducted an experiment to study the performance of Udaipur rock phosphate and superphosphate. Phosphorus was given as rock phosphate (PR), SSP or a mixture of the two sources in a 1:1 ratio at rates of 0. 12.9, 25.8, 38.7 or 51.6 kg P ha'^{1}. Filled grains panicle^{1}, 1000-grain weight, and yield increased with increasing P rate upto a plateau at 38.7 kg ha'^{1}. SSP and the mixture were more effective than PR only in increasing yield and yield components.

Mitra *et al.* (1992) conducted field trials with rock phosphate (PR) alone. SSP alone or as a mixture of both on lateritic, red and alluvial soils. They stated that PR significantly increased rice yield in lateritic and red soils. A mixture of PR and SSP (l:lratio) gave grain yields as good as those with SSP. The yield response was red soil > lateritic soil > alluvial soil.

Several phosphate rocks (PRs) and soluble triple superphosphate (TSP) were evaluated by Heliums *et al.* (1992) as phosphorus fertilizers on acid soils. In the Colombian experiments PR increased yields more than did TSP for the initial maize crop and also provided some residual P to the first wheat crop. Annual applications of Tilemsi PR and TSP, on a P deficient soil in Mali, provided similar significant yield increases for maize and cotton in two different cropping rotations. The experiments in Indonesia showed that ground North Carolina PR was as effective (as a source of P nutrition) as TSP in both annual and residual maize soybean trials. Economic analysis showed that in every trial the PRs were as economically effective as soluble TSP in providing available P to all crops under the conditions tested.

Fageria *et al.* (1991) carried out a field experiment with rice-common bean rotation. They observed that in the first year, TSP and 2 partially acidulated phosphate rocks produced higher grain yields. In the remaining years the efficiency of phosphate rock sources as measured by grain yield was equivalent to TSP or partially acidulated P sources. It was suggested that these PR sources could be used in rice/*Phaseolus vulgaris* rotations on Brazilian oxisol.

Hardjono (1991) carried out an experiment in Indonesia and reported that PR can replace TSP as a source of fertilizer P for rubber, oil palm, cocoa and leguminous cover crops grown on acid soil.

Partohardjono and Adiningsih (1991) conducted an experiment of PR use in annual cropping systems in Indonesia and concluded that reactive PR when directly applied at initial rates between 80 and 360 kg P:C>5 ha^{-1}, not only increased yields of com, upland rice, soybean and groundnut on Ultisol and Oxisols but also gave similar or even larger yield than TSP.

Siddaramappa *et al.* (1991) carried out an experiment on acid soil in Karnataka, India and noticed that the highest grain yield of 5.64 t ha^{-1} was recorded for rice supplied with Udaipur rock phosphate (UPR) at 60 kg ha^{-1}, followed by 5.49 t ha^{-1} with super phosphate at 60 kg ha^{-1}, the lowest yield of 2.86 t ha^{-1} was in the control.

Verma *et al.* (1991) carried out an experiment on rice cv. Saket where phosphorus was applied at the rate of 60 kg P2O5 ha^{-1} as superphosphate and mussoorie rock phosphate (PR). The respective grain yields from the treatments were 4.07 and 3.05 t ha^{-1}, compared with the control of 2.86 t ha^{-1}.
Chien *et al.* (1990) reported that the substitution value of a P fertilizer is the ratio of total P applied in standard fertilizer like TSP to total P required in a test fertilizer to give the same yield. They also said the substitution value is larger with rock phosphate (PR) indicating PR is more profitable than TSP.

Bandyopadhyay (1989) conducted an experiment to see the effect of lime, superphosphate and rock phosphate in the Sunderban acid sulphate soils in India with rice crop. He noted that PR had better effect than superphosphate and suggested to use it in place of superphosphate for increasing agricultural production.

Balasubramaniyan (1989) conducted an experiment to show the direct and residual effects of Mussoorie rock phosphate on rice. The author found that P increased the number of panicle m‘~ and evaluated that the highest yield to rice was obtained with 50% P as PR and pyrites in 1:5 ratio + 50% P as SSP gave the highest yield in comparison to other ratio.

Marwaha *et al.* (1989) reported that the indigenous PR was beneficial as a source of P on acidic soils. It is also reported that one equivalent P levels of PR can hardly equalize SSP in crop yield.

Pujari *et al.* (1989) conducted an experiment to see the efficiency of rock phosphate in rice-groundnut crop sequence in north coastal Karnataka. The authors found that the highest total yields and gross returns were obtained with 60 (rice) + 30 (groundnut) kg P2O5 ha ' as SSP + PR, followed by 30 + 30 kg P_20_5 ha$^{'!}$ also as SSP + PR whereas yields and gross returns were lower with P as SSP or PR only.

Thongbai *et al.* (1988) carried out an experiment on acid sulphate soil at Prachinbari, Thailand, with an annual applications of 8.7 kg P ha$^{'1}$ or 35.0 or 140 kg P ha$^{'1}$ in the first year, as TSP or rock phosphate (PR). All the treatments increased growth and yield, PR being more effective than TSP. Grain yield increased from an average 1.8 t ha$^{'1}$ in control to a maximum of 3 t ha ^{1} with 140 kg P ha' as PR. The superiority of PR was due to its effect in releasing P bound in the acid sulphate soil.

Seyoum and Mcintire (1987) evaluated that direct application of ground rock phosphate (PR) to crops grown on acid soil is a simple and low cost method of substituting refined phosphates, especially if the PR is locally available. The relative agronomic and economic effectiveness of phosphate rocks has been examined using data from the literature. In general, phosphate rocks gave lower agronomic responses than refined phosphates, but the yields were well above the control. The economic effectiveness of PR could be improved by using more concentrated rock, which would reduce transportation and other related costs.

Muller *et al.* (1986) undertook a long term experiment to investigate the effects of various types of phosphorus fertilizer conversion in soil. They found that partially decomposed and sintered rock phosphates performed well. They also noted that application of large amount of phosphorus gave a significant value to increase the yields of cereals.

Singh and Gangwari (1986) stated that rice grown on a clay acid soil (pH 5.7) with an application of 100 kg P2O5 ha'1 as rock phosphate, single superphosphate or their mixture gave 3 years average paddy yield of 3.65, 3.2S and 3.33-3.53 t ha'1 respectively, compared with 2.67 t ha'1 without P. Increasing the proportion of rock phosphate in the mixtures increased yield.

Datta and Gupta (19S5) in two field trials with paddy, where P supplied as rock phosphate, single superphosphate, and bonemeal, singly and in various combination, reported that rock phosphate produced the highest paddy yields.

Attanandana and Vacharotyan (1984) compared rock phosphate (PR) with triple superphosphate (TSP) on rice growth and yield in pots and in the field on acid sulphate soils. They found that PR gave better response than TSP. They also suggested that mild liming was necessary for good yields on very acid soils (pH 4.5) but high rates reduced P availability from PR. According to them PR gave the best residual effect.

Yillarroel and Augstburger (1984) observed that for potato production in soils with varied pH ranging from 4.6 to 6.5, the average 9.5% improved response to 120 kg P; of ha^{-1} from the PR was not statistically superior to the check where no P was applied. However, the yield response to TSP was low and TSP was statistically superior to the PR in only 3 of the 13 sites.

In a comparative study with SSP, bonemeal and rock phosphate alone and in various combinations of them. Datta and Gupta (1983) found that rock phosphate produced the highest yield of paddy in both direct application and residual effect.

Sahu and Pal (1983) conducted a field trial in a rice-wheat cropping system on acid soils with different rock phosphates and concluded that the highest P uptake and yield of rice were obtained with 50:50 mixture of Mussoorie rock phosphate (MPR) and superphosphate (SP) in comparison to 100% MPR and SP.

Nair and Padmaja (1982) conducted a pot trial with rice in five soil types to show the efficiency of primed rock phosphate for grain production. The authors found that the efficiency of 45 kg P2O5 ha [1] as PR applied to moist aerobic soil 1-2 weeks before flooding was similar to or higher than (depending on soil type) that of superphosphate in increasing paddy yields.

2.2 Dry matter yield as influenced by rock phosphate and P uptake

Issak (2005) carried out a field experiment to study the influenced of rock phosphate (PR) in comparison to TSP as a source of P on growth yield and nutrient uptake of rice crop. The results indicated that the dry matter yield increased significantly due to fertilization with PR.

Subadh *et al.* (2003) conducted a pot experiment to investigate the efficiency of rock phosphate and superphosphate (SP) mixture (3:1, 1:1 and 1:3; PR: SP) in dhaincha- rice crop sequence. Results showed that all the mixtures of PR and SP significantly increased the dry matter yield and P uptake by dhaincha over control or

PR alone. Among the mixtures PR + SP (1: 3) was the most efficient in terms of yield and P uptake, this mixture (PR + SP, 1: 3) showed the highest residual effect in terms of grain yield and total P uptake by rice.

Rodrigueze *et al.* (2002) reported that partial acidulation (PA) of some rock phosphate (PR) was found to be highly effective compared to their natural PR in terms of dry matter production, P uptake and isotopic parameters.

Brasil *et al.* (2002) evaluated the relative agronomic efficiency of TSP and North Carolina phosphate rock (NCPR) at the rate of 0, 40, 80 and 120 mg P kg'[1] soil. The results showed that the best dry matter yield and P uptake for cowpea were obtained in soils fertilized with TSP but the best residual effect was obtained with NCPR.

Chien (2002) reported that the effectiveness of P sources in terms of increasing dry matter yield and P uptake followed the order of TSP> (PR + TSP)> PR for maize and TSP = (TSP + PR)> PR for cowpea. P uptake from PR in presence of TSP was higher than P uptake from PR applied alone. With respect to P uptake from PR applied alone, the corresponding relative increase in P uptake from PR due to TSP influence was 165% for maize and 72° o for cowpea.

Ravi *et al.* (2001) conducted a field experiment consisted of 15 treatment with three replications, which includes water soluble sources like single superphosphate (SSP) and monoammonium phosphate (MAP), insoluble sources like maton rock phosphate (MRP), gafsaphos. North Carolina rock phosphate (NCRP). Jordan rock phosphate JPR (A) and JPR (B) and compaction of JPR (A) or (B) with SSP, MAP and MAP + S. Result showed that the grain yield and P uptake by both main and residual crop during the first and second year were maximum with non compacted JPR (A).

In a field experiment Sharma *et al.* (2001) investigated the effect of incorporation of wheat *(Triticum aestivum*) and rice *(Oryza saliva*) residue on the relative efficiency on diammonium phosphate and mussoorie rock phosphate in rice (cv. Pusa 169) wheat (cv. HD 2329) cropping system. The study indicated that the incorporation of crop residue not only increased the grain yield and P uptake of rice and available of P build up.

Somado *et al.* (2001) reported the effect of rock phosphate (PR) combined w ith a pre-rice green manure (GM) on rice yield. From the results grain yield increased averaged over GM was 1. 6 fold (PR) and two-fold triple superphosphate (TSP) above the no-P control treatments. Application of TSP to the legume resulted in 62% more rice dry biomass as compared to P applied alone to rice. Combined PR + GM resulted in a 64% yield increased over PR alone. PR application in the present of GM increased rice P uptake.

Bado and Hien (1998) conducted a comparative experiment on the agronomic efficiency of Burkina Faso rock phosphate (BPR) and TSP on upland rice with annual phosphate input levels of 0, 13, 26 and 39 kg P ha . Results showed that application of TSP or BPR increased P absorption and rice yield. Rice uptake of phosphorus was better with TSP.

Bado and Hien (1998) conducted a comparative experiment on the agronomic efficiency of Burkina Faso rock phosphate (BPR) and TSP on upland rice with annual phosphate input levels of 0, 13, 26, and 39 kg P ha^1. Results showed that application

of TSP or BPR increased rice yield. In the first year, the two phosphates had the same agronomic efficiency on rice yield; while BPR more efficiently increased rice yield than TSP in the second year. BPR was found well adapted and economically suitable for upland rice fertilization.

Sundaresan *et al.* (1983) conducted an experiment in 6 different acid soils to show the efficiency of Mussoorie rock phosphate and superphosphate on yield characters of rice. The authors found that there was no significant difference in response to superphosphate and rock phosphate as 45 or 90 kg P:0_5 ha'^{1} on the grain and straw yields and chemical composition of grain and straw of rice.

2.3 Nutrient content in rice and nutrient uptake as influenced by rock phosphate

Issak (2005) carried out an experiment to study the effect of direct application of rock phosphate (PR) in comparison to TSP as a source of P. The N, P, K and S content as well as uptake by rice plant were increased due to application of PR (210 kg P ha').

Islam (2005) conducted two experiments in two agro-ecologically different sites to study the effects of different treatments on growth and yields of rice. The N, P. K and S nutrients content and uptake significantly increased due to application of PR and TSP.

Rahman (2005) conducted two experiments in two different regions, one at BIN A sub-station, Comilla and another at BRRI sub-station, Rajshahi to study the effect of different treatments of PR and TSP on growth and yield of rice. The N. P, K and S content and uptake significantly increased due to higher rate of application of PR compared to other treatments.

Subadh *et al.* (2003) conducted a pot experiment to investigate the efficiency of rock phosphate and superphosphate (SP) mixture (3:1, 1:1 and 1:3; PR: SP) in dhaincha- rice crop sequence. Among the mixtures PR + SP (1: 3) showed the highest residual effect in terms of grain yield and total P uptake by rice.

Sankhajit *et al.* (2000) conducted a field experiment to study the effects of rock phosphate (60, 100 and 150 kg P ha'^{1}) and superphosphate (60 kg P ha*^{1}) on the nutrient content and yield of rice. At the vegetative stage, the highest total nitrogen (1.45%), phosphorus (0.29%) and potassium (0.75%) contents were recorded for rock phosphate at 150 kg P ha'^{1}, superphosphate at 60 kg P ha'^{1} and rock phosphate at 100 kg P ha'^{1}, respectively. At the maturation stage, the highest percentage of total N (1.036) and K (0.78) were accumulated in plants with PR at 100 kg P ha'^{1}. Rock phosphate at 150 kg ha'^{1} gave the highest K content (0.66%). Variation in crop yield due to PR or superphosphate application were not significant.

Bado and Hien (1998) conducted a comparative experiment on the agronomic efficiency of Burkina Faso rock phosphate (BPR) and TSP on upland rice with annual phosphate input levels of 0, 13, 26, and 39 kg P ha^{1}. Results showed that rice uptake of phosphorus w as better with TSP, probably because of its solubility, while BPR also increased Zn and Al uptake.

Mongia *et al.* (1998) carried out a greenhouse experiment and showed that The response of rice to P was more as compared to lime. P application considerably reduced the Al content of both grain and straw, it had also a depressing effect on Fe uptake. However, P application increased Mn content without any definite trend.

Datta and Gupta (1985) in two field trials with paddy, with P supplied as rock phosphate, single superphosphate, and bonemeal, singly and in various combinations, reported that uptake of P was increased by the phosphates while solubility of Zn in soils and its concentration in grain were decreased.

Datta and Gupta (1983) made a comparative study with SSP, bonemeal and rock phosphate alone and in various combinations of them. In two field trials they found that the application of PR increased the availability of Ca in soils and the uptake of P, K and Ca by rice plant.

2.4 Effect of rock phosphate on chemical properties of soil

2.4.1 CEC and proton availability

Agbenin (2004) suggested to utilize rock phosphate (PR) as an effective source of P management practices that increased Ca sink and the supply of protein to the soils. In the Savana, increasing the soil organic matter greatly enhances cation exchange capacity (CEC) and availability of protons. The practice should provide adequate sink for Ca'" and the acidic environment required for the release of P from PR.

2.4.2 P availability

Bogdevitch *et al.* (2002) conducted an experiment to study a comparative evaluation of P availability from PR and mono ammonium phosphate (MAP). The lupine was grown on sod-podzolic silty clay loam soil with pH 6.0 and a medium level of available P. Application of PR and MAP at a rate of 40 mg P kg ^{1} supplied similar moderate amount of P to lupine plants. The result of the pot experiment suggested that direct application of PR may be more effective than the use of water soluble P fertilizers.

Ortega and Rojas (1999) found that P availability in soil was increased by P application as SSP, TSP or rock phosphate.

Marwaha *et al.* (1989) reported that one of the major problems of acid soil in the low availability of both native and applied phosphate due to the dominance of Fe^{3}\ Al^{3+}, $Mn^{'+}$ etc. An indigenous PR was beneficial as a source of P in acid soil.

2.4.3 Soil pH

Rosamalin *et al.* (1999) conducted an experiment where the phosphate fertilizers used were rock phosphate (PR) in combination with TSP with or without liming. The treatments combination were PR 100%, PR 75% + TSP 25%, PR 50% + TSP 50%, PR 25% + TSP 75% and TSP 100%. The soil analyses showed that pH of the unlimed soils were between 4.4-4.5 while the pH of the limed treatments were between 4.6-4.9.

2.4.4 Other nutrient in soil

Bado and Hien (1998) conducted a comparative experiment on the agronomic efficiency of Burkina Faso rock phosphate (BPR) and TSP on upland rice with annual phosphate input levels of 0, 13, 26 and 39 kg P $ha^{'1}$. Results showed that application of TSP or BPR increased P absorption and rice yield. Rice uptake of phosphorous was better with TSP, probably because of its solubility, while BPR also increased Zn and Al uptake.

Datta and Gupta (1983) made a comparative study with SSP, bonemeal and rock phosphate alone and in various combinations of them. In two field trials they observed that the application of PR increased the availability of Ca in soils and the uptake of P, K and Ca by rice plant but decreased the solubility of Cu, Zn and Fe in soils and their concentration in paddy grain.

2.5 Residual effects

Ghosal *et al.* (2003) conducted an experiment to study the relative agronomic effectiveness (RAE) of rock phosphates (PR) as compared to water soluble triple superphosphate (TSP) on direct, residual and cumulative application. The RAE of the rock phosphates were lower for direct application (54-80%) and cumulative application (70-93%) of P but roughly equal or larger for the residual effect (92-142%) as compared to TSP.

Ravi et al. (2001) conducted a field experiment consisted of 15 treatment with three replications, which includes water soluble sources like single superphosphate (SSP) and monoammonium phosphate (MAP), insoluble sources like maton rock phosphate (MRP), gafsaphos, North Carolina rock phosphate (NCRP), Jordan rock phosphate JPR (A) and JPR (B) and compaction of JPR (A) or (B) with SSP, MAP and MAP + S. The result showed that among the compacted sources, JPR (A) and (B) with MPA + S recorded higher main and residual effect compared to other P fertilizer in terms of agronomic productivity of rice-groundnut cropping sequence.

Melgar *et al.* (1998) reported that in field trials at 3 sites in corrientes, Argentina, rice cv. IRGA was given 0, 13, 27 or 40 kg P ha^{-1} as triple superphosphate or North Carolina rock phosphate. Both sources gave similar results at equal application rates, both for direct and residual effect.

Adiningsih and Rochayati (1992) conducted an experiment on farmers fields in Lampung Province Sumatra’s soils showed that the application of 1.0 t ha^{-1} reactive PR followed by the planting of Mucuna, a fast growing leguminous cover crop, successfully suppressed the regrowth of imperata grass and had long residual effect which significantly increased crop yields on degraded soil.

Partohardjono and Adiningsih (1991) conducted a field experiment on the direct application of PR for various upland crops including com, upland rice, soybean and peanut as well as lowland rice and concluded that long term basis, reactive PR was as effective as TSP.

Krishnappa *et al.* (1991) carried out an experiment to study the efficiency of rock phosphate in coastal Karnataka, India. Phosphate was applied at 30 and 60 kg P_20_5 ha^{-1} as superphosphate (SP), rock phosphate (PR) and as mixture of the two at 1:2 proportions. Application of phosphate in the form of PR alone or its combination w'ith SP gave higher total productivity compared with SP alone at both levels of application. The residual effect of rock phosphate appeared to be the most pronounced in the second crop for groundnut.

Sara Sawudyotin (1987) reported that rock phosphate was more effective than TSP for the unlimed treatment. The grain yield in the rock phosphate treatment was five times the TSP application. The residual effect of rock phosphate was superior to TSP in terms of grain producing without liming. The grain yield was 20% higher in the rock phosphate application.

Attanandana and Vacharotyan (1984) compared rock phosphate (RP) with triple superphosphate(TSP) on rice growth and yield in pots and in the field on acid sulphate soils. They found that higher rates of liming reduced P availability from PR. According to them PR gave the best residual effect.

2.6 Net profit due to application of rock phosphate

Issak (2005) carried out a field experiment to study the influence of rock phosphate (PR) in comparison to TSP as a source of P on growth yield and nutrient uptake of rice crop. The results indicated that the judiciously mixed application of PR and TSP was more effective and beneficial due to its appropriate availability for plants over longer period of time and at comparatively low cost.

Tomita *et al.* (2001) conducted a two year experiment to study the effect of phosphate rock at 0, 50, 100, 200 and 400 kg P2O5 ha^{-1} on rice cv. Panama-1048. Data were presented which increased profits compared with lime and TSP application.

Sankhajit *et al.* (1999) carried out a field experiment to compare the effect of different doses of rock phosphate with the recommended dose of superphosphate with or without green manuring in a rice-mustard cropping system. Through superphosphate (60 kg P ha^{-1}) gave the highest net profit of Rs 23 thin 421 without green manuring and of Rs 31 thin 785 with green manuring, rock phosphate application (100 kg P ha^{-1}) also provided similar net profits of Rs 21 thin 281 without green manuring and of Rs 31 thin 905 with green manuring. Considering the benefit cost ratio, both sources in the control plots were found equally effective but in green manured plots PR @ 100 kg ha^{-1} was superior.

Goswami and Baroova (1998) conducted a field experiment on an acid soil, in a rice-wheat sequence was given 0, 30, 60 or 90 kg P ha^{-1} as single superphosphate

(SSP), diammonium phosphate (DAP), Mussoorie rock phosphate (MPR) or Purulina rock phosphate (PPR) showed that, MPR and PPR gave higher yields than SSP or DAP and the highest net return was recorded with MPR at 90 kg ha^{1}.

Bado and Hien (1998) conducted a comparative experiment on the agronomic efficiency of Burkina Faso rock phosphate (BPR) and TSP on upland rice with annual phosphate input levels of 0, 13, 26 and 39 kg P ha^{1}. Results X showed that in the first year, the two phosphates had the same efficiency on rice yield, while BPR more efficiently increased rice yield than TSP 1 in the second year. BPR seems well adapted and economically suitable for upland rice fertilization.

Several phosphate rocks (PRs) and soluble triple superphosphate (TSP) were evaluated by Heliums *et al.* (1992) as phosphorus fertilizers on acid soils. Economic analysis showed that in every trial the PRs were as economically effective as soluble TSP in providing available P to all crops under conditions tested.

Marwaha *et al.* (1989) reported that the indegenous PR was beneficial as a source of P on acidic soils. It is also reported that cost effective variable attempts have been made to increase the efficiency of PR.

Quin (19S9) described the commercial introduction of reactive phosphate rock (PRR) and partially acidulated phosphate rock (PAPR) in Newzealand according to the following stages: i) Agronomic assessment ii) publication of research findings iii) commercial introduction of RPR iv) opposition from manufactures and v) eventual out come. The Newzealand experience suggests that for the introduction into established fertilizer markets of low-cost direct application RPR and its PAPR to be successful, the following ingredients are required: i) independently conducted or monitored agronomic research ii) an independent agency with the responsibility for overseeing the correct promotion of these products to farmers iii) fertilizer companies with a long term commitment to the nations agriculture or Government/private enterprize joint ventures, iv) an independent agency with the responsibility for monitoring chemical composition of products v) an independent arbiter or fair trading legislation for the setting of disputes between parties.

Seyoum and Mcintire (1987) evaluated that direct application of ground rock phosphate (PR) to crops grown on acid soil is a simple and low cost method of substituting refined phosphates, especially if the PR is locally available. The relative agronomic and economic effectiveness of phosphate rocks has been examined using data from the literature. The economic effectiveness of PR could be improved by using more concentrated rock, which would reduce transportation and other related costs.

2.7 Economic efficiency or Agronomic effectiveness

Goh and Chew (1995) investigated the relative economic efficiency of different P sources in rubber and found that PR was less costly by 68% typic tropudults and by 30% on typic paleudults. Agronomic effectiveness of PR is higher than soluble P source like TSP, SSP due to lower cost of PR.

Ng *et al.* (1993) mentioned that the effect of one time application of 300 kg $P_{:}0_5$ as TSP was compared with the same amount of P_20_5 supplied as PR from china PR, Jordan PR and North Carolina PR on growth of a legume cover crop, *Mucuna* *cochinchinensis* and subsequent maize crops. They concluded that effectiveness of PR and TSP are equal.

Misra *et al.* (1992) cited that Udaipur PR could profitable be used for acid soils if powdered finely to pass through 100 mesh sieve and was as effective as superphosphate for rice in acid soils.

Kpomblekon *et al.* (1991) conducted two greenhouse experiment to compare the agronomic effectiveness using a Relative Agronomic Efficiency (RAE) index for different phosphorus sources. The results showed that ground Togo PR was an effective P source for both maize and cowpeas. The RAE values were not significantly different from those for the control (no P added) for the partially acidulated PR and compacted (PR+TSP), however, the RAE values with respect to SSP were 72.5% and 84.7%.

Bellott Montalvo (1991) conducted field trials at Bolivian soils in Latin America and observed raw rack phosphate has had little effect on potatoes and cereals but has given better responses from maize and rice. Good responses were obtained when the partially acidulated rock phosphate was applied to wheat and potatoes.

Results from studies to compare the agronomic effectiveness of various P fertilizers are discussed by Chien *et al.* (1990). They reported that fertilizer effectiveness is very dependent on fertilizer properties, soil properties, application techniques and crop species. Under right conditions, phosphate rock and partialh acidulated phosphate rock can be as effective as water-soluble P fertilizers.

Friesen *et al.* (1990) summarized results from five annual food crop farming system experiments on representative acid upland soils in central and Southern

Sumatra where PR were compared with TSP. They concluded that medium and high reactively PRs are, for all practical purposes as effective as equivalent soluble P sources like TSP, SSP etc

Hammond *et al.* (1986) cited that PR have high agronomic effectiveness compared with TSP where soil with low pH, low soil solution P, exchangeable Ca and P sorption capacity and w'arm moist climate.

Sadler and Stwart (1984) cited that tropical acid soils are very low in native P and most of the water slouble P in added fertilizer is sorbed. In such a situation, the use of locally available phosphate rock (PR) is a potentially economically attractive. They also said that considerable portion of fertilizer P not used by first crop immediately which is available to succeeding crops.

Bandy and Leon (1983) concluded that the PR was equally effective as TSP and offered as a good substitute for imported fertilizer.

Goedert (1983) found that patos, Araxa and Catalao PRs were only 43%, 36% and 20% effective in case of agronomic performance as TSP when measured over six annual crops.

Rajan (1982) worked with different rock phosphate in Newzealand in a greenhouse study to evaluate phosphate rocks as P sources. He compared partially acidulated rock phosphates (PAPRS) with superphosphate and found that PAPRS were more effective than superphosphate.

Chapter III

MATERIALS AND METHODS

This chapter contains materials and methods of two experiments carried out both in same field in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro- ecological zone of Modhupur Tract, AEZ-28. The field trials were conducted under the rice-rice cropping pattern during Boro and T. aman season of 2005. In the first boro rice crop various amount of P from different sources (TSP and PR) were applied and their residual effect was observed in the fallowing T. aman rice crop. The physico-chemical analysis of soil and chemical analysis of plants were carried out in the laboratory. The materials and methods of this two experiments are presented under the following site:

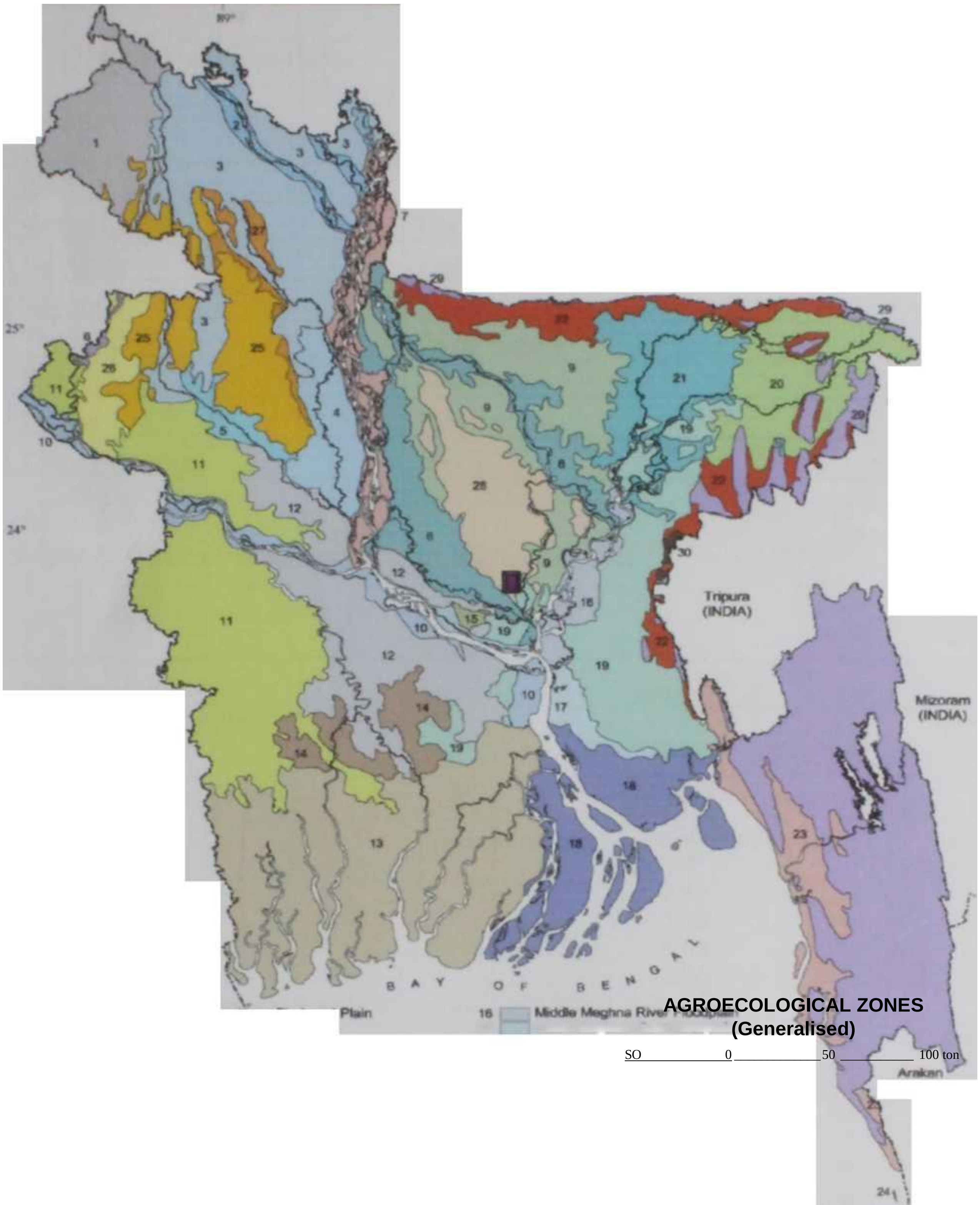
3.1 Experimental detailed of the site

3.1.1 Experimental site and soil

Two field experiments were conducted in the same site in a typical rice growing soil of Bangladesh under Sher-e-Bangla Agricultural University Farm, Dhaka, during Boro and T. aman season of 2005. The farm belongs to the general soil type, Deep red brown Terrace soils under Tejgaon series. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of initial soil are presented in (Table 1 and 2).

3.1.2. Climate

The climate condition of the experimental area are characterized by high temperature, high humidity and moderate to heavy rainfall with occasionally gusty wind during kharif season (16 March to 15 October) and low rainfall accompanied by moderate low temperature and humidity during Rabi season (16 October to 15 March). The average temperature and rainfall data during the cropping period are shown in appendix I and II.



OH Himalayan AdM Tala Ftootfptam DM
Msandar Floodplari Karataya-Bangs I
Fkxx^Mm Low Altai Basn Loam
Pi«iart)t>aba Floodplain Acbvc
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Brahmaputra Floodplam AcMve Ganges
Floodplain High Ganga* River Ftaodplafri
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22 ■i Northern and Eastern Piedmont
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28 Madhupur Tract
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Assam
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Fig. 1. Map showing the experimental sites under study I

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Table.1. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ	Madhupur Tract
General Soil Type	Deep red brown terrace soils
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Rice-Rice

Table 2. Chemical properties of the initial soil

Characteristics	Value
Particle size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Table 3. Characteristics of the initial soil (Boro rice BRRI Dhan 29)

Treatments	PH	Organic matter (%)	Total nitrogen (%)	Available S (ppm)	Available P (ppm)	Exchangeable K (meq 100 g'^{1} soil)
Ti Control (0 kg P ha^{1})	5.50	0.88	0.048	10.43d	26.50d	0.113c
T_2 PR (35 kg P h a ')	5.80	0.86	0.052	13.18bc	28.75c	0.125b
T_3 TSP (35 kg P h a ')	5.90	0.87	0.047	14.37b	32.50b	0.135a
T_4 PR (210 kg P h a ') ***	5.75	0.88	0.048	10.68cd	28.00c	0.125b
T_5 PR (17.5 kg P ha'^{1}) + TSP (17.5 kg P h a ')	6.00	0.89	0.048	20.18a	34.00a	0.140a
Level of significance	NS	NS	NS	**	**	**
CV %	5.25	4.95	6.06	3.04	7.84	6.93

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

***** - Applied for previous crop**

**** = Significant at 1% level of significance**

3.1.3. Crops

BRR1 Dhan 29 and BRRI Dhan 30 were used as test crop. Both of this two variety are high yielding variety of Boro and T. aman rice respectively. Among this variety BRRI Dhan 29 was used as first crop in the first experiment and BRRI Dhan 30 was as second crop in the field experiment. Both the variety were develops by Bangladesh Rice Research Institute (BRRI), Joydepur, Gazipur. This variety is now widely grown in Bangladesh for their high yield potential with low susceptibility to disease.

3.1.4 Land preparation

First experimental Field was First opened on 1st January, 2005 and second experiment was opened on 30th June, 2005 with the help of a power tiller, later the land was saturated with irrigation water and prepared by three successive ploughing and cross-ploughing. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the Field. The experimental plots were laid out as per treatment and design.

3.1.5 Experimental design

Design: Randomized Complete Block Design (RCBD).

Treatment: 5

Replication: 4

Total number of plots: 20

Plot size: **8**m x 5m

Block to block distance: lm

Plot to plot distance: 0.3 m

3.1.6 Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Each block was Sub-divided into Five unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 20 (5 x 4). The unit plot size was Sm x 5m. The spacing between blocks was 1 m and between plots 0.3 m. the layout of the experiment has been shown in Fig. 2.

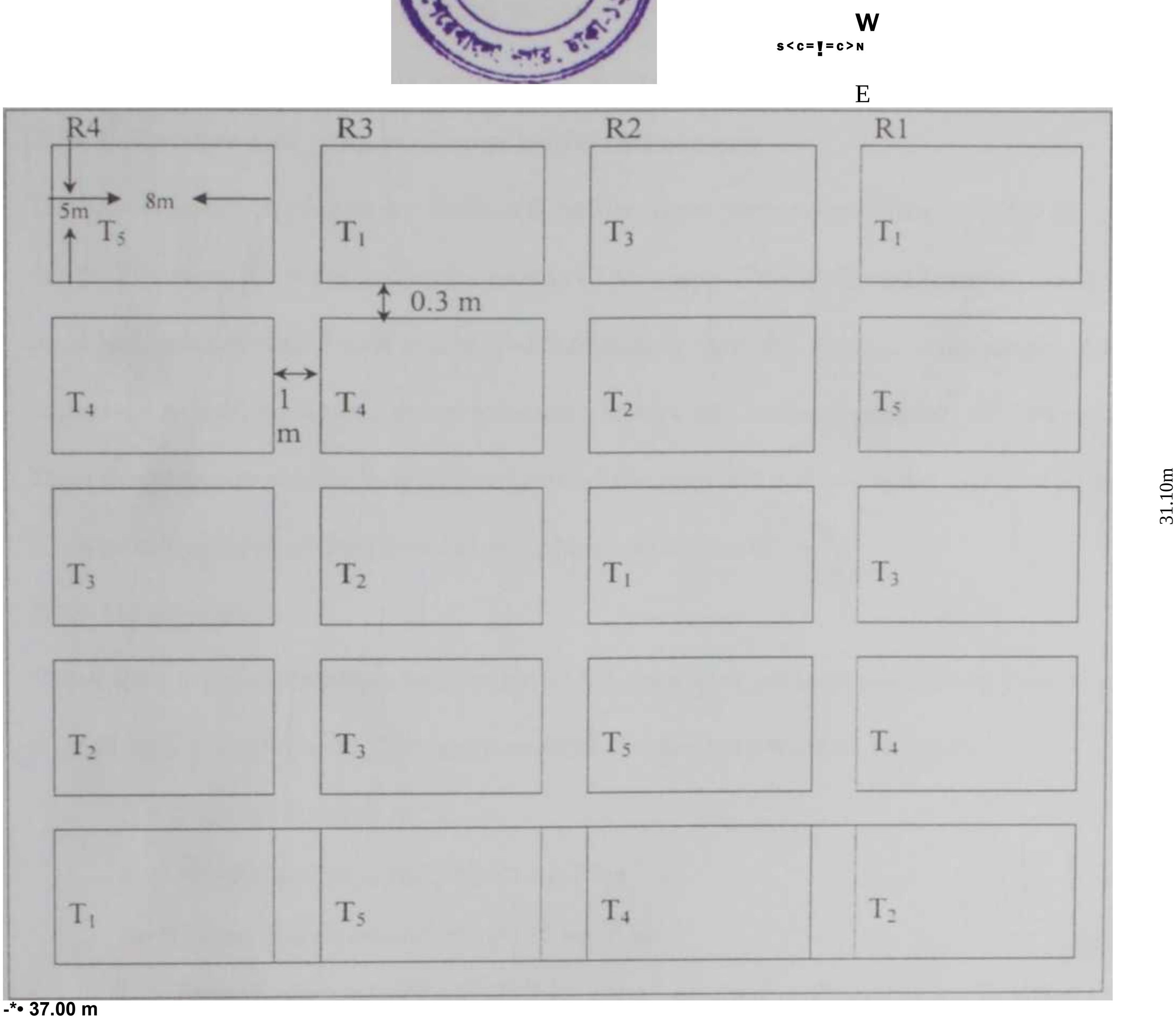


Fig. 2. Layout of the experiment

3.1.7. Raising of seedlings

A common procedure was followed in raising of seedlings in the seedbed. For this purpose, a previously prepared land was selected. The nursery bed was prepared by puddling the wetland with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed. No fertilizer was used in the nursery bed.

3.1.8 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.1.9 Treatments

There were five treatments consisting of TSP, two dose of rock phosphate, one mixed dose of rock phosphate & TSP and a control. Treatments were as follows:

T[= Control (0 kg P ha ').

Ti = Phosphate rock (PR) @ 35 kg P ha’^{1} T_3 = Triple Super phosphate @ 35 kg P ha"^{1}

T_4 = Phosphate rock (PR) @ 210 kg P ha'^{1} applied in the previous T. aman rice crop in 2004

T_5 = Phosphate rock (PR) @ 17.5 kg P ha*^{1} + TSP @ 17.5 kg P ha’^{1}

3.1.10 Application of fertilizers

All the amount of phosphatic fertilizers were applied during land preparation except T_4. In the treatment T_4 210 kg P ha ^{1} from PR was applied in previous T. aman rice crop in 2004. A blanket dose of 75:50:20:3 kg ha^{1} of N, K, S and Zn was applied as urea, muriate of potash, gypsum and zinc oxide, respectively. All the fertilizers, except urea were added to the soil during final land preparation. Urea was applied in three equal splits. The first split was applied during land preparation, the second split after 30 days of transplanting i.e. at active vegetative stage and the third split after 60 days of transplanting i.e. at panicle initiation stage. The fertilizer was thoroughly mixed with the soil by hand. The amount of available P**2**O**5** of different sources of P that were used in the treatments are shown in appendix III. Second crop was grown only with recommended nitrogen fertilizer.

3.1.1I Description of the Phosphate Rock (PR)

Phosphate rock is a raw material of Triple super phosphate (TSP) fertilizers. Morocco PR was used as the test P fertilizer in the Boro and T-aman season 2005.Moreover PR content of 29.75% P**2**O**5**. PR is slow soluble P source which release P slowly. It prevents P fixation in acid and alkaline soils due to less solubility.

3.1.12 Transplanting of seedling

The seedlings of 32 days old were transplanted in the first experimental plots on 13 February, 2005 and the second experimental plots on **6**th July, 2005. Plant spacing was 25 cm * 15 cm. The number of rows and hills were equal in all plots. The seedlings were carefully uprooted from the seedbed before transplanting. Three seedlings were used per hill.

3.1.13 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop. Top dressing of urea was done as per schedule and the normal cultural practices including weeding and insecticides spray were done as and when necessary. There were some incidence of insect attack specially rice hispa, rice stem borer, rice bug, which were controlled by spraying Diazinon pillersuphan, Darsban and Malatheon. Irrigation was also done uniformaly to the plots and maintained on water level of 5 to 4 cm throughout the growing period of the crops.

3.1.14 Sampling at maximum tillering (MT) stage and panicle initiation (PI) stage

The first crop (main) at maximum tillering stage on 25 ^{h} March and panicle initiation stage on 9^{,h} April. Second crop (residual) at maximum tillering stage on 7 ^{h} August, 2005 and panicle initiation stage on **8**^{lh} September. 2005. 10 hills were harvested randomly by cutting at the ground level. The harvested hills were first air dried and then oven dried at 70° C for 48 hrs. To get the dry matter yield and finally stored for nutrient analysis.

3.1.15 Plant Sampling at harvest

10 hills were randomly selected from each plot to record the yield contributing characters like plant height (cm), number of tillers hill^{1}, panicle length (cm), number of srains panicle'^{1}, and 1000 grain weight (g). The selected hills were collected before harvesting. Grain and straw yields were recorded plot-wise and expressed at t ha' on sun-dry basis.

3.1.16 Harvesting

The first (main) crop was harvested at maturity on 30th May, 2005 and second (residual) crop was harvested at maturity on 29th October, 2005. The harvested crop was threshed plot-wise. Grain and straw yields were recorded separately plot-wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw were also recorded.

3.1.17 Data collection

The data on the following yield contributing characters of the crop were recorded as follows:

- **i)** Plant height (cm).
- **ii)** Number of effective & uneffective tillers per hill
- **iii)** Panicle length (cm)
- **iv)** Unfilled and filled grains per panicle
- **v)** 1000-grain weight
- **vi)** Grain and straw yields (kg/plot)

3.1.17.1 Plant height (cm)

The plant height was measured from the ground level to the top of the tallest panicle. Plants of 10 hills were measured and averaged for each plot.

3.1.17.2 Number of tillers per hill

Ten hills were taken at random from each plot and the number of tillers per hill was counted. The numbers of effective and uneffective tillers per hill were also determined.

3.1.17.3 Panicle length

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

3.1.17.4 Unfilled and filled grains per panicle

Ten panicles were taken at random and the unfilled and filled grains per panicle were counted and averaged.

3.1.17.5 1000 grain weight

The weight of 1000-grains from each plot was taken after sun drying by an electrical balance.

3.1.17.6 Grain and straw yields

Grain and straw yields were recorded separately plot-wise and expressed as t ha ‘ on 14% moisture basis.

3.1.18 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of the Division of Soil Science, Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. The properties studied included texture, pH, organic matter, total N, available P. exchangeable K and available S. The physical and chemical properties of the initial soil have been presented in Table 2. The soil was analyzed following standard methods:

Particle-size analysis of soil was done by Hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values tor % sand, % silt and ^{J}o clay to the “Marshall's Textural triangular coordinate” following the USDA system.

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

Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). The underlying principle is to oxidize the organic carbon with an excess of IN $K_2Cr_20_7$ in presence of conc. H_2S0_4 and to titrate the residual $K_2Cr_20_7$ solution with IN $FeS0_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

Total nitrogen of soil was determined by micro Kjeldahl method where soil was digested with 30% H_20_2, conc. H_2S0_4 and catalyst mixture (K_2S0_4: $CuS0_4$. $5H_20$: Se powder in the ratio of 100:10:1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate traped in H**3**BO**3** with 0.01 N H_2S0_4 (Bremner and Mulvaney, 1982).

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_2$ solution of pH 8.5 (Olsen ***et al.*** 1954). The phosphorus in the extract was then determined by developing blue colour using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue colour was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of a standard curve.

Exchangeable potassium was determined by IN NH_4OAC (pH 7.0) extract of the soil by using flame photometer (Black, 1965).

Available sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page ***et al***., 1982). The S content in the extract was determined turbidimetrically and the intensity of turbid was measured by spectrophotometer at 420 nm wavelength.

3.1.19 Chemical analyses of plant samples

3.1.19.1 Preparation of plant samples

Ten selected hills per plot were collected immediately after harvest of the crop. The selected hills were threshed. Both grain and straw were cleaned and dried in an over at 65°C for 48 hours. The dried samples were then ground with a grinder. The prepared samples were put into small paper bags and kept into a dessicator till being used.

3.1.19.2 Digestion of plant samples with sulphuric acid

For N determination an amount of O.lg plant sample (grain/straw) was taken into a 100 ml Kjeldahl flask. An amount of 1.1 g catalyst mixture (K_2S0_4: $CuS0_4$. $5H_20$:Se = 100:10:1), 2ml 30% H_2O_2 and 3ml conc. H_2S0_4 were added into the flask. The flask was sw'irled and allowed to stand for about 10 minutes, followed by heating at 200°C. Heating was continued until the digest was clear, and colourless. After cooling, the contents were taken into a 100 ml volumetric flask and the volume was made with distilled water. A reagent blank was prepared in a similar way. This digest was used for determining the nitrogen contents in plant samples.

3.1.19.3 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5 g of sub-sample was taken into a dry clean 100 ml. Kjeldahl flask, 10 ml of di-acid mixture (HNO_3, $HC10_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature raising slowly to 200°C. Heating was instantly stopped as soon as the dense white fumes of $HC10_4$

occurred and after cooling, 6ml of 6N HC1 were added to it. The content of the flask was boiled until they become clear and colourless. This digest was used for determining P, K and S.

3.1.19.4 Determination of elements in the digest

Nitrogen content in the digest was determined by similar method as described in soil analysis. Phosphorus content was determined following the procedure as described in the soil analysis section.

Potassium concentration of the digest was determined directly by flame photometer. Sulphur concentration in the digest was estimated turbidimeterically by a spectrophotometer using 420 nm wave length**.**

3.1.20 Statistical Analysis

The statistical analysis for different characters including the nutrient content and uptake were done following the ANOVA technique and the mean results in case of significant F-values were adjusted by the Duncan’s Multiple Range Test (DMRT).

Chapter IV

J

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to the application of different rate, of phosphate rock and TSP on growth, yield, and crop productivity ot rice (cv. BRRI Dhan 29 as Boro rice) and its residual effect onsucceding rice crop (cv. BRRI Dhan 30 as T. aman). The analytical results of the studies such as dry matter yield, nutrient content and nutrient uptake by rice at maximum tillering stage and at panicle initiation stage as well as at harvest are discussed in this chapter. The results and discussion are presented below:

4.1 First crop (Boro rice cv. BRRI Dhan 29)

4.1.1 Dry matter yield

The dry matter yield of Boro rice was determined at the time of maximum tillering and panicle initiation stages while straw and grain yields were recorded at the maturity.

The effect of different treatments was insignificant as observed on dry matter accumulation at maximum tillering stage (Table 4 and figure 3). The highest dry matter yield (2.70 t ha'^{1}) was obtained in T_5 (PR 17.5 kg P ha - TSP P.5 kg P ha^{1}) treatment The lowest dry matter yield (2.09 t ha'^{1}) was obtained in T (control) treatment.

Total dry matter production at panicle initiation stage w as significantly increased over the control due to application of 35 kg P ha' and the mixture of phosphate rock and TSP fertilizer (T_5). The highest dry matter w eight of 5.93 t

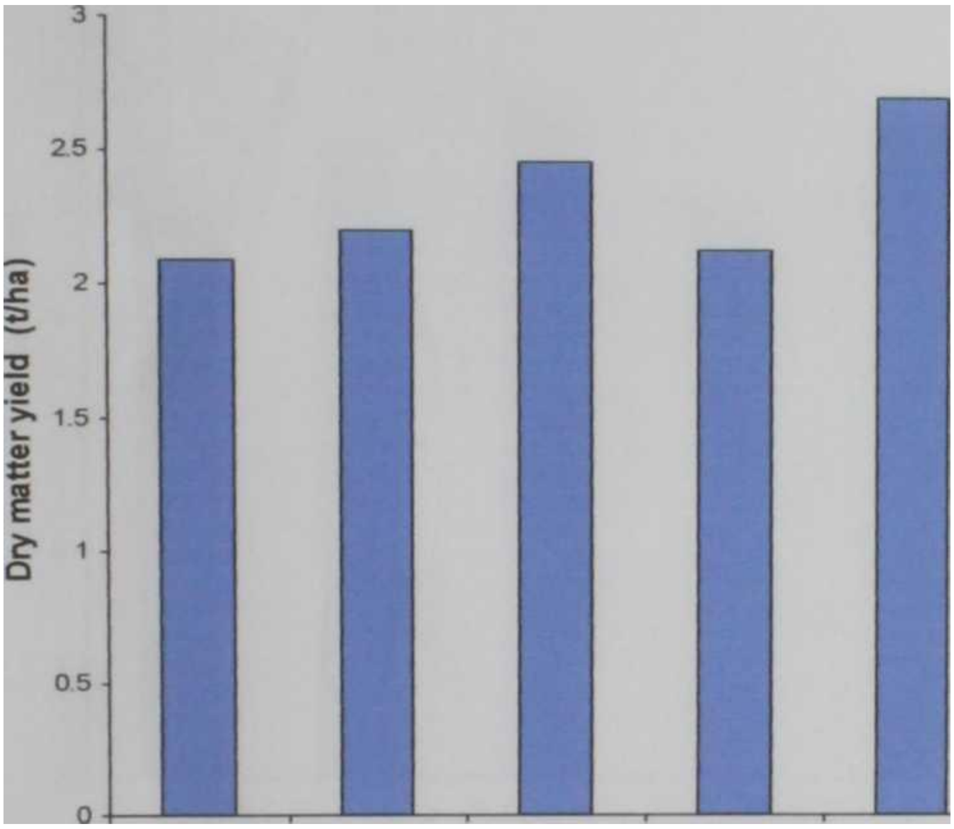
Treatments	At MT stage	At PI stage
	Dry matter Yield (t ha*1)	Dry matter Yield « ha1)
T| Control (0 kg P ha'1)	2.09	4.86 b
T_2 PR (35 kg P ha'1)	2.20	5.51 ab
T, TSP (35 kg P ha*1)	2.46	5.93 a
T_4 PR (210 kg Pha1) ***	2.13	5.00 ab
T_s PR (17.5 kg P ha*') + TSP (17.5 kg Pha'1)	2.70	5.66a
Level of significance	NS	**
CV%	15.18	12.26

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

NS = Non significant

*** = Applied in previous crop in 2004

** = Significant at 1% level of significance



T1 Control (0 72 PR (35 kg T3TSP(35kg T4 PR (210 kg T5 PR (17 5 kg kg RTha) P*ha)

Plba) Pma) RTha) + TSP

(17.5 kg F*ha)

Treatments

Fig. 3 Effect of differnet treatmens on dry matter yield at maximum tillering (MT) stage of Boro rice

T1 Control (0 T2 PR (35 kg T3 TSP (35 kg T4 PR (210 kg T5 PR (17.5 kg kg P/ha) P/ha)
P/ha) P/ha) P/ha) + TSP
(17 5 kg P/ha)

Treatments

Fig. 4 Effect of diffemet treatmens on dry matter yield at panicle initiation (PI) stage of Boro rice

ha^{4} was observed in T_3 treatment, which was statistically similar with T_5 treatment. The minimum dry matter yield (4.86 t ha^{-1}) was observed in control. In producing dry matter yield at PI stage, the treatments may be arranged in order of $T_3 > T_5 > T_2 > T_4 > T$ Rahman (2005) and Issak (2005) also reported similar trends of total dry matter production at PI stage due to application of different rates of PR and TSP.

4.1.2. Yield and yield contributing characters

4.1.2.1 Plant height

Plant height, one of the agronomic characteristics, was found to be statistically insignificant in all treatments used in the experiment. The maximum plant height (89.15 cm) was attained in the treatment T> and the minimum plant height of rice plants (85.82 cm) was obtained in T| treatment (Table5).

4.1.2.2 Total tillers hill

The effect of different treatments on total tillers hill'[1] was statistically significant. The maximum number of tiller hill'[1] (14.07) was obtained in T_5 (PR 17.5 kg P ha‘‘ + TSP

17.5 kg P ha"[1]) treatment The treatments T_5 and T_3 increased total number of tillers per hill over the control (T[) treatment In producing total number of tillers hill'[1], the treatments may be arranged as Tj > T_3 >Ti > T_4 > T1. Rahman (2005) stated that total number of tillers hill'[1] significantly increased with the application of PR.

4.1.2.3. Effective tillers hill'[1]

Combined application of PR&TSP (T_5) and full dose of TSP (T_3) increased effective tillers per hill significantly over the control (Table 5). The maximum number of effective tillers hill'[1] (11.40) was obtained in T_5 (PR 17.5 kg P ha' - TSP 17.5 kg P ha'[!]) treatment. The lowest number of effective tillers hill (9.37) was obtained in T|

(control P_0) treatment. Judicious application of PR and TSP increased effective tillers hill Rahman (2005) and Issak (2005) similar results were reported by.

4.1.2.4 Panicle length

Panicle length was not influenced significantly although there was some apparent difference in panicle length in different fertilizer treatments over control (Table 5). Maximum panicle length (28.00 cm) was attained in T_5 treatment and minimum panicle length (24.20 cm) was attained in control treatment.

4.1.2.5 Unfilled grains panicle"[1]

Table 5 shows the effects of different treatments on unfilled grains panicle[1]. It was found that unfilled grains panicle'[1] to be statistically significant. The highest unfilled grains (27.79) obtained in T! (control P_0) treatment which was statistically identical to T_2 (PR 35 kg P ha[1]) and T_5 treatments. The lowest unfilled grains (20.15) was obtained in T_5 (PR 17.5 kg P ha'[1] + TSP 17.5 kg P ha'[1]) treatment which was significantly lower than T_b T_2 and T_4 treatments. It was observed that the combined application of PR and TSP decreased unfilled grains panicle' .The percentage of unfilled grains panicle'[1] ranged from 20.25 to 13.36. Issak (2005) reported that unfilled grains panicle'[1] and their percent significantly decreased with the application of PR.

4.1.2.6 Filled grains panicle [1]

The filled grains panicle'[1] varied significantly among the treatments (Table 5). The highest number of filled grains panicle'[1] (130.63) was obtained in the treatment T_5 (PR

17.5 kg P ha'[1] + TSP 17.5 kg P ha[1]), which was significantly greater than the T_4 and

T, treatments. The second highest filled grains panicle'[1] (125.60) was produced by the T_3 (TSP 35 kg P ha ') treatment which was superior to T_3, T_2 and T, treatments. T_3 was superior to T_2 while T_2 was superior to Tj (control P_0). The lowest filled grains panicle'[1] (110.50) was obtained in treatment T_t (control P_0). It was observed that filled grains panicle [1] increased due to combined application of PR and TSP. All the treatments may be arranged according to their superiority as a $T_5>T_3>T_2>T_4>T|$. Rajkhowa ***et al*** (1998) reported that the filled grains panicle'[1] increased with increasing P rate as a mixture of Udaipur rock phosphate (URP) and Superphosphate (1:1 ratio) up to a plateau at 38.7 kg ha'^1.

4.1.2.7 1000-grain weight

The results (Table 5) indicated that the effects of different treatments on 1000-grains weight were statistically in significant. The highest **1000**-grain weight of 20.60 was found in T_5 and the lowest 19.50 in treatment T_t. Rajkhowa ***et al*** (1998) reported that the 1000-grains weight increased with increasing P rate as a mixture of URP and Superphosphate (1:1 ratio)up to a plateau at 38.7 kg ha^{-1}.

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Table 5. Effect of different treatments on yield contributing characters of Boro rice (BRRI Dhan 29) at harvest

Treatments	Plant height (cm)	Total tillers hill[1] (No.)	Effective tillers hill[1] (No.)	Panicle length (cm)	Unfilled grain panicle'[1] (No.)	Percent unfilled grain	Killed grains panicle [1] (No.)	Percent filled grain	1000-grain weight (g)
T, Control (0 kg P ha'[1])	85.82a	12.00c	9.37b	24.20a	27.79a	20.25a	110.50c	79.74c	19.50a
T_2 PR (35 kg P h a ')	89.15a	13.92abc	10.15ab	26.10a	25.62ab	17.74ab	118.83abc	82.25abc	20.15a
T, TSP (35 kg P ha'[1])	8f>.47a	I4.30ab	10.30a	26.70a	21.67bc	I4.69bc	I25.60ab	85.30ab	20.40a
T_4 PR (210 kg P h a [1]) * * *	85.95a	12.45bc	10.20ab	25.60a	26. lOab	18.84a	112.40bc	81.15bc	19.70a
T_s PR (17.5 kg P h a ') + TSP (17.5 kg P ha ')	88.47a	14.70a	11 40a	28.00a	20.15c	13.36c	130.63a	86.63a .	20.60a
Level of significance	NS	* +	**0	NS	**	**	*	*	NS
CV%	4.13	7.12	7.07	9.34	9.70	10.13	7.41	3.95	7.14

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

NS = Non significant

*** = Applied in previous crop in 2004

** = Significant at 1% level of significance

* = Significant at 5% level of significance

4.1.3 Yield

4.1.3.1 Grain yield

The effects of different treatments on grain yield of Boro rice (cv. BRRI dhan 29) revealed a significant variation (Table 6). The grain yield varied from 5.80 to 6.80 t ha '. The maximum yield (6.80 t ha^{-1}) was noted in treatment T_5 (PR 17.5 kg P ha^{-1} - TSP 17.5 kg P ha^{-1}) which was significantly greater than Tj treatment. The lowest grain yield was (5.30 t ha ') obtained in T] (control P_0) treatment. The second highest yield (6.60 t ha^{-1}) was obtained in treatment T_3 (TSP 35 kg P ha^{-1}) which was superior to T: (PR 35 kg P ha ') and Ti treatments. In producing grain yield, the treatment may be ranked in order of T_5> T_3> T_2> T_4> Ti. The result might be due to judicious application of PR and TSP on rice field which resulted in more effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which contributed to increased grain field. Mitra ***et al*** (1992) stated that PR significantly increased rice yield in lateritic and red soils. A mixture of PR and SSP (1:1 ratio) gave grain yields as good as ***those*** with SSP. The yield response was red soil > lateritic soil > alluvial soil. The mixture of URP & SSP at **1:1** ratio was more effective than PR only in increasing yield (Rajkhowa ***et al*** 1998). They also reported that SSP and the mixture of SSP & URP were more effective than URP in increasing yield and yield components. Rahman (2005) reported that rice grain at harvest stage was increased significantly due to application of higher rate of PR. Pohcegoudar ***et al.*** (1994) stated that rock phosphate and acidulate rock phosphate increased rice yield compared to SSP.

4.1.3.2 Straw yield

The effect of different treatments on the straw yield of rice was markedly influenced (Table **6**). The highest straw yield (7.47 t ha'[1]) was recorded in T_5 (PR 17.5 kg P ha'**[1]** - TSP 17.5 kg P ha ') treatment which was significantly superior to other treatments. The second highest straw yield (7.27 t ha ') was obtained in treatment T_3, which is statistically similar to the treatment T_5. Application of full dose of PR (T_2), full dose of TSP (T_3), and mixture of PR and TSP (T_5) increased straw yield significantly over the control (Tt). Thongbai ***et al.*** (1988) reported that PR increased rice yield over control. Similar result was found Issak (2005). Misra ***et al*** (2002) found that application of modified PRs significantly increased dry matter yield of the crops. Das ***et al*** (1999) also reported that the dry matter yield was significantly increased due to mixed application of PR and SSP (1:1 ratio).

4.1.4 Nutrient content and uptake by rice plant at maximum tillering (MT) stage

4.1.4.1 N content and uptake

Results in Table 7 revealed the effect of different treatments on N content at maximum tillering stage. The N content due to different treatments ranged from 2.70% to 3.2% at this stage. The minimum N content was recorded in the control, which was statistically identical to T_2 and T_4 treatments. The treatment T_5 exhibited the highest N content, which was also statistically identical to T_2. T_3 and T_ treatments. The treatment T:. and T_5 increased N content significantly over the control. The N uptake by rice plant was found statistically significant

Table 6. Effect of different treatments on grain and straw yields of rice (BRRI Dhan 29)

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
T_1 Control (0 kg P ha^{-1})	5.8 c	6.50 b
T_2 PR (35 kg P ha^{-1})	6.1 d	6.60 ab
T_3 TSP (35 kg P ha^{-1})	6.6 b	7.27 a
T_4 PR (210 kg P ha^{-1}) ***	6.3 c	6.52 ab
T_5 PR (17.5 kg P ha^{-1}) + TSP (17.5 kg P ha^{-1})	6.8 a	7.47 a
Level of significance	*	**
CV%	9.23	6.83

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

= Applied in previous crop in 2004

= Significant at 1% level of significance

*** =** = Significant at 5% level of significance

□ Grain yield ■

Straw yield

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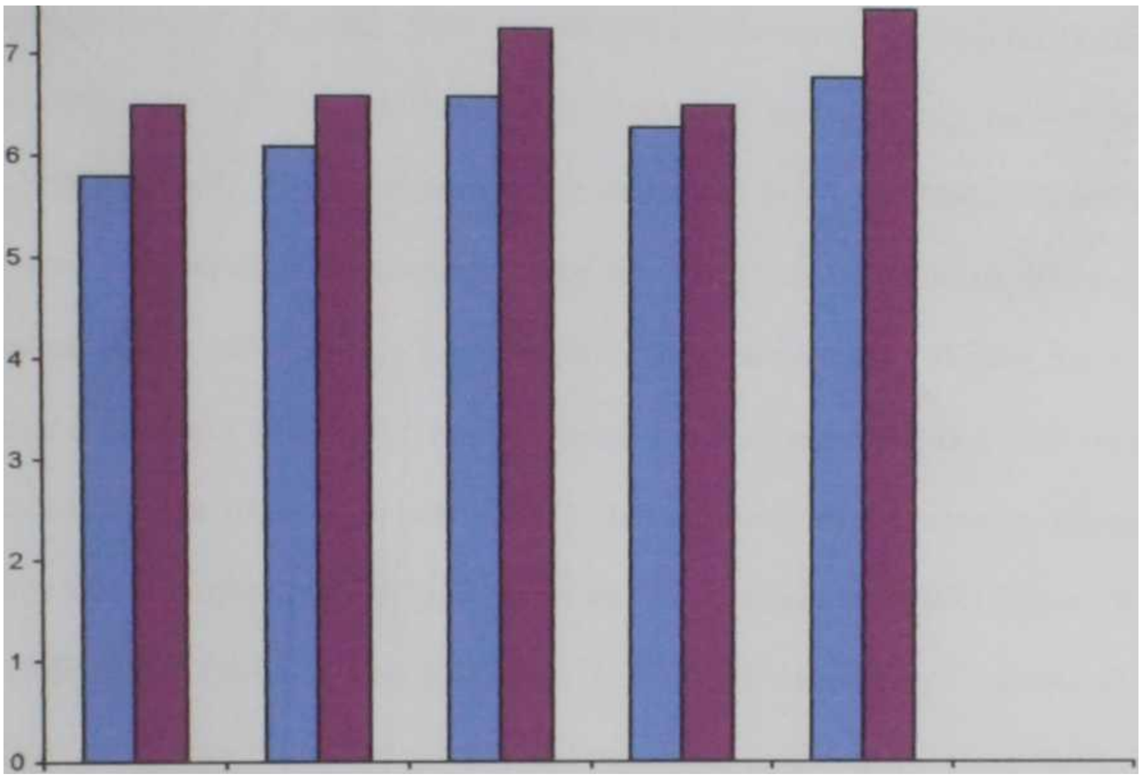
n



Grain and Straw yield (t/ha)

T1 Control (0 T2 PR (35 kg T3 TSP (35 kg T4 PR (210 kg T5 PR (17 5 kg kg P/ha) P/ha)

P/ha) P/ha) P/ha) ♦ TSP

(17 5 kg P/ha)

Treatments

Fig. 5 Effect of diffemet treatmens on grain and straw yield of Boro rice

due to different treatments. The highest N uptake (86.4 kg ha'[1]) was observed in T_5 treatment and the lowest N uptake (56.57 kg ha ') was noted in control. The N uptake by Ti and T_4 treatments were statistically identical. All the P treatment, except the application of 210 kg P as PR applied in the previous crop (T_4), increased N uptake by the crop compared to the control. The N content and uptake by rice plant was increased due to application of PR (Islam, 2005).

4.1.4.2 P content and uptake by rice plant

Application of PR and TSP in different combinations markedly increased the concentration of P in rice plant. The P content in rice plant ranged from 0.19%to 0.24% (Table 7). The maximum value was noted in the treatment T_5 and the low est P content was recorded in control treatment. The P content due to different treatments ranked in the order of T_5>T_4>T_3>T_2>Ti. T_5 treatment had shown better effect over other treatments, indicating that judicious application of PR and TSP increased the P content in rice plant. Rahman (2005) also reported an increase in P content at MT stage due to higher rate of application of PR. P uptake by BRRI Dhan 29 also varied significantly (Table 7). The treatment T< obtained maximum P uptake (6.4S kg ha'[1]) where as the control treatment showed minimum P uptake (4.02 kg ha'). P uptake by $T_{:}$, T_3 and T_4 were statistically identical. However, the treatments T_3 and T> increased P uptake significantly over the control. An increase in P uptake at MT stage due to higher rate of application of PR was also reported by Rahman (2005).

Treatments	Nutrient content (%)				Nutrient uptake (kg ha)			
	N	P	K	S	N	P	K	S
T| Control (0 kg I* ha [1])	2.70b	0.19d	2.02c	0.14b	56.57d	4.02c	42.36c	3.04b
T_2 PR (35 kg P ha[1])	3.01 ab	0.20cil	2.l5bc	0.16ab	66.37c	4.54bc	47.37c	3.52b
T, TSP (35 kg P ha'[1])	3.07a	0.22b	2.34ab	0.16ab	73.85b	5.35ab	56.33b	4.03ab
T_4 PR (210 kg P ha'[1]) ***	2.94ab	0.21 be	2.15bc	0.14b	62.79cd	4.51 be	45.94c	3.16b
T_5 PR (17.5 kg P ha[1]) + TSP (17.5 kg P ha*[1])	3.20a	0.24a	2.57a	0.17a	86.40a	6.48a	69.44a	4.80a
Level of significance	**	*	★*	**	**	**	**	**
CV%	5.26	8.37	6.10	7.84	5.30	10.82	6.13	12.24

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT ***

= Applied in previous crop in 2004 ** = Significant at 1% level of significance *= Significant at 5% level ol

significance

4.1.4.3 K content and uptake by rice plant

Results in Table 7 showed that the K content in rice plant was significantly influenced due to different treatments. The highest K content (2.57%) was observed in T_5 treatment, which was identical to T**3** treatment and minimum value (**2.02**%) was obtained in control. The K content due to different treatments ranked in the order of T_5>T_3>T_2>T_4>T,.

K uptake also showed significant response due to different treatments. The highest K uptake (69.44 kg ha'[1]) was recorded in T_5 treatment and the lowest K uptake (42.36 kg ha'[1]) was found in the control and K uptake due to different

treatments ranked in the order of T_5>T_3 > T_2>T_4 >Tj. The results revealed that full dose of TSP (T_3) and the mixture of PR and TSP (T_5) enhanced K. uptake significantly over the control. The K content as well as uptake by rice plant increased due to application of PR (Islam, 2005 and Issak, 2005).

4.1.4.4 S content and uptake by rice plant

A significant increase in S content by rice plant was recorded in $T_?$ treatment over the control and other treatments (Table 7). The highest value (0.171%) was obtained in T_5 treatment. The minimum value (0.141%) was obtained in T].

S uptake by rice plant also significantly increased due to the application of 50% TSP and 50% PR treatment (T_5). The highest S uptake was found in T_5 treatment (4.8 kg ha'[1]) and the lowest S uptake (3.04 kg ha') was obtained in control treatment. The treatments T|, T_2, T_3 and T_4 were statistically identical in respect of S uptake. Islam (2005) observed an increase in S uptake by rice plant due to application of PR.

4.1.5 Nutrient content and uptake at panicle initiation (PI) stage

4.1.5.1 N content and uptake by rice plant.

Results in Table **8** showed that the N content in rice plant at PI stage was significantly influenced by different treatments. The maximum N content (1.70%) was obtained in T_5 treatment and control treatment showed the minimum N content (1.35%) in control treatment which was statistically identical to T_2, T_3 and T_4 treatments.

N uptake by BRRI Dhan 29 also varied significantly. The highest N uptake (96.22 kg ha'^{1}) was obtained in T_5 treatment and the minimum value (59.21kg ha^{1}) was noted in control treatment. The treatment T_2 and T_3 were statistically identical. All the P treatments (T_2, T_3, T_4, and T5) increased N uptake significantly over the control. All the P treatment. The N content and uptake by rice plant was increased due to application of PR (Islam, 2005).

4.1.5.2 P content and uptake by rice plant

The effects of PR and TSP on P content of Boro rice was influenced significantly at panicle initiation stage, which was presented in (table **8**). The highest P content (0.14%) was recorded in T> (PR 17.5 kg P ha ^{1} + TSP 17.5 kg P ha^{1}) treatment. The second highest P content (0.12%) was found in T_3 treatment, which was statistically identical to T_5 treatment. The lowest P content (0.09°**0**) was found in T! treatment. The treatments T_3 and T_5 increased P content in rice plant significantly over the control (Ti)

There was a significant increase in P uptake in response to effects of PR at panicle initiation stage of rice (TableS). The highest P uptake (8.62 kg ha $^{!}$) with the application of T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha'^{1}) treatment was statistically superior as compared to T, treatment. The second highest P uptake (7.23 kg ha^{-1}) was obtained in treatment T_3. The lowest P uptake (4.05 kg ha ') was observed in treatment T| The treatments T_2, T_3 and T_5 increased P uptake significantly over the control. Application of 210 kg P as PR in the previous crop failed to increase P uptake significantly. This might be due to insoluble nature of PR. Issak (2005) reported that the P content and uptake significantly increased due to the mixed application of rock phosphate (PR) and triple superphosphate (TSP). Krishchenppa ***et al.*** (1991) reported that root, foliage and grain increased with increasing P levels.

4.1.5.3 K content and uptake by rice plant

The K content in BRRI Dhan 29 at panicle initiation stage was significantly influenced by different treatments and ranged from 1.67% to 2.20% (Table **8**). The highest value was obtained in treatment T_5 and control treatment showed the minimum K content.

K uptake by rice plant responded significantly due to different treatments and ranged from 73.16 to 135.52 kg ha^{-1}. The highest K uptake (135.52 kg ha^{-1}) was noted in T_5 treatment and the lowest value (73.16 kg ha^{-1}) was found in control. Islam (2005) reported that the K content and uptake by nee plant increased due to application of PR.

Treatments	Nutrient content (%)				Nutrient uptake (kg ha)			
	N	p	K	S	N	P	K	S
Ti Control (0 kg P ha[1])	1.35b	0.09c	0.67c	0.20b	59.2 Id	4.05c	32.56c	8.85c
T_2 PR (35 kg P ha'[1])	1.57b	0.l0bc	0.84hc	0.21b	86.51b	5.79b	46.28c	11.57bc
T_3 TSP (35 kg P ha'*)	1.57b	0.12ah	0.96b	0.22ab	93.10b	7.23a	56.92b	13.34ab
T_4 PR (210 kg Pha'[1])***	1.45b	0.l0bc	0.85bc	0.21b	72.75c	5.25bc	42.5d	10.5bc
T_s PR (17.5 kg P ha[1]) + TSP (17.5 kg P ha'[1])	1.70a	0.14a	1.20a	0.23a	96.22a	8.62a	67.96a	14.66a
Level of significance	**	**	♦ ♦	♦ ♦	**	**	**	**
CV%	9.74	10.48	4.72	4.43	4.44	10.42	3.60	10.88

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by **DMRT** ***

= Applied in previous crop in 2004 ** = Significant at 1% level of significance

4.1.5.4 S content and uptake by rice plant

Result presented in **1** able **8** showed that S content was increased significantly due to different treatments. S content in rice plant ranged from 0.20% to 0.23%. The maximum value was noted in the treatment T**5** and the control treatment produced minimum S content.

S uptake by rice plant responded significantly due to different treatment. The highest S uptake (14.66 kg ha'[1]) was obtained in T_5 treatment and the lowest value (8.85 kg ha [!]) was found in control and the S uptake ranged from 8.85to 14.66 kg ha**'[1]** (Table **8**). The treatments T**3** and T**5** were statically identical and significantly grater than the control. S content and uptake were increased at PI stage due to higher rate of application of PR (Rahman, 2005).

4.1.6 Nutrient content and uptake in grain and straw

4.1.6.1 N content in grain and straw

The effect of different treatments on N content in grain was statistically significant (Table 9). It was found that the higher rates and combined application of PR and TSP increased the N content in grain. The highest N content (1.37%) w as found in T_5 (PR

17.5 kg P ha'[1] + TSP 17.5 kg P ha ') treatment, which was statistically significant as compared to control but statistically similar with T_2, T_3 and T_4 treatments. The lowest N content was found in T] (control) treatment.

In case of straw, N content was statistically significant (Table 9). The highest N content (1.56%) in straw was found in T_5 (PR 17.5 kg P ha'[1] + TSP 17.5 kg P ha) treatment, which was statistically significant compared to control treatment. The lowest **N** content **(0.885%)** was found in **T[** treatment. Islam (2005) also reported that **N** content in grain and straw were maximum by the application of PR.

4.1.6.2 N uptake in grain and straw

The effect of different treatments on N uptake by grain was influenced statistically significant (Table 9). The effect of different treatments increased N uptake by grain. The highest N uptake (86.12 kg ha^{-1}) was found in T_5 (PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}) treatment, which was statistically significant as compared to control (T]) treatment. The second highest N uptake by T_3 (35 kg P ha^{-1} from TSP) treatment. The lowest N uptake (56.95kg ha^{-1}) was found in T| treatment.

In case of straw, N uptake ranged from 57.52 to 108.59 kg ha^{-1} and was statistically significant (Table 9). The highest N uptake (108.59 kg ha ') was found in T_5 (PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}) treatment. The lowest uptake (57.52 kg ha^{-1}) by straw was found in Tj treatment.

The total N uptake was also statistically significant. (Table 9 & Figure 7) The highest total N uptake (197.63 kg ha^{-1}) was found in T_5 (PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}) treatment. The lowest total N uptake (116.33 kg ha^{-1}) was found in T, treatment, which was statistically inferior to all other treatments.

Tabic 9. Effect of different treatments on N concentration and N uptake by Boro rice (BRRI Dhan 29) at harvest stage

Treatments	Content (%)		Uptake (kg ha'[1])		Total uptake (kg ha ')
	Grain	Straw	Grain	Straw	
T| Control (0 kg P ha'[1])	0.982b	0.885b	56.95d	57.52d	116.33d
T_2 PR(35 kg Pha'[1])	1.145ab	1.635ab	69.84c	74.91c	147.53c
T_3 TSP (35 kg Pha[1])	1.200ab	1.237ab	79.2b	89.92 b	171.55b
T_4 PR (210 kg P ha'[1]) ***	1.145ab	0.955b	72.13c	62.26cd	136.49c
T_5 PR (17.5 kg P ha'[1]) + TSP (17.5 kg P ha'[1])	1.367a	1.558a	86.12a	108.59a	197.63a
Level of significance	*	*	**	♦♦	**
CV%	8.70	10.57	3.74	4.28	4.86

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT ***

= **Applied** in **previous crop** in **2004 ** = Significant at 1% level of significance**

* **- Significant al 5% level of significance**

Phosphorous content and uptake by grain and straw at harvest

4.1.6.3. P content in grain and straw

The effect of different treatments on P content in grain was statistically significant (Table 10). It was observed that P content increased with increasing level of P by PR and TSP. The highest P content (0.20%) in grain was obtained in T_5 (PR 17.5 kg P ha' ^{1} + TSP 17.5 kg P ha) treatment which was statistically significant to control (Ti). The second highest P content (0.19%) was found in T_3 treatment. The lowest P content (0.15%) was found in T] treatment.

The effect of different treatments on P content in straw was statistically significant (Table 10). The highest P content (0.20%) in straw was found in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha^{-1}) treatment. The lowest P content (0.16%) was found in ^ treatment.

4.1.6.4 P uptake in grain and straw

The P uptake by grain was statistically significant (Table 10) due to effects of different treatments. The highest P uptake (13.95 kg ha'^{1}) by grain was observed in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha^{1}) treatment, which was statistically significant with T|, T_2 and T_4 treatments but statistically similar to T_3 (35 kg P ha") treatment.

In case of straw, P uptake was statistically significant (Table 10). The highest P uptake (15.46 kg ha'^{1}) by straw was found in T_5 (PR 17.5 kg P ha $^{!}$ — TSP 17.5 kg P ha ’) treatment, which was statistically similar to T**3** treatment. Combined application of TSP and PR (T_5) and full dose of TSP (T_3) increased P uptake significant over the control. The lowest P uptake by straw (9.9 kg ha'^{1}) was

Table 10. Effect of different treatments on P concentration and P uptake by Boro rice (BRRI Dhan 29) at harvest stage

Treatments	Content (%)		Uptake (kg ha'1)		Total uptake (kg ha'1)
	Grain	Straw	Grain	Straw	
T| Control (0 kg P ha'1)	0.150c	0.165b	7.95c	9.9c	17.85c
T_2 PR (35 kg P ha1)	0.180b	0.168b	10.98b	11,09bc	22.07bc
T_3 TSP (35 kg P ha ')	0.192ab	0.180b	12.67ab	13.09ab	25.76ab
T_4 PR (210 kg P ha'1) ***	0.173b	0.160b	10.90b	10.43bc	21.33bc
T_s PR (17.5 kg P ha'1) + TSP (17.5 kg P ha1)	0.205a	0.207a	13.94a	15.46a	29.4a
Level of significance	**	**	**	**	**
CV%	4.89	9.69	11.47	11.08	8.99

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT *** =

Applied in previous crop in 2004 ** = Significant at 1% level of significance

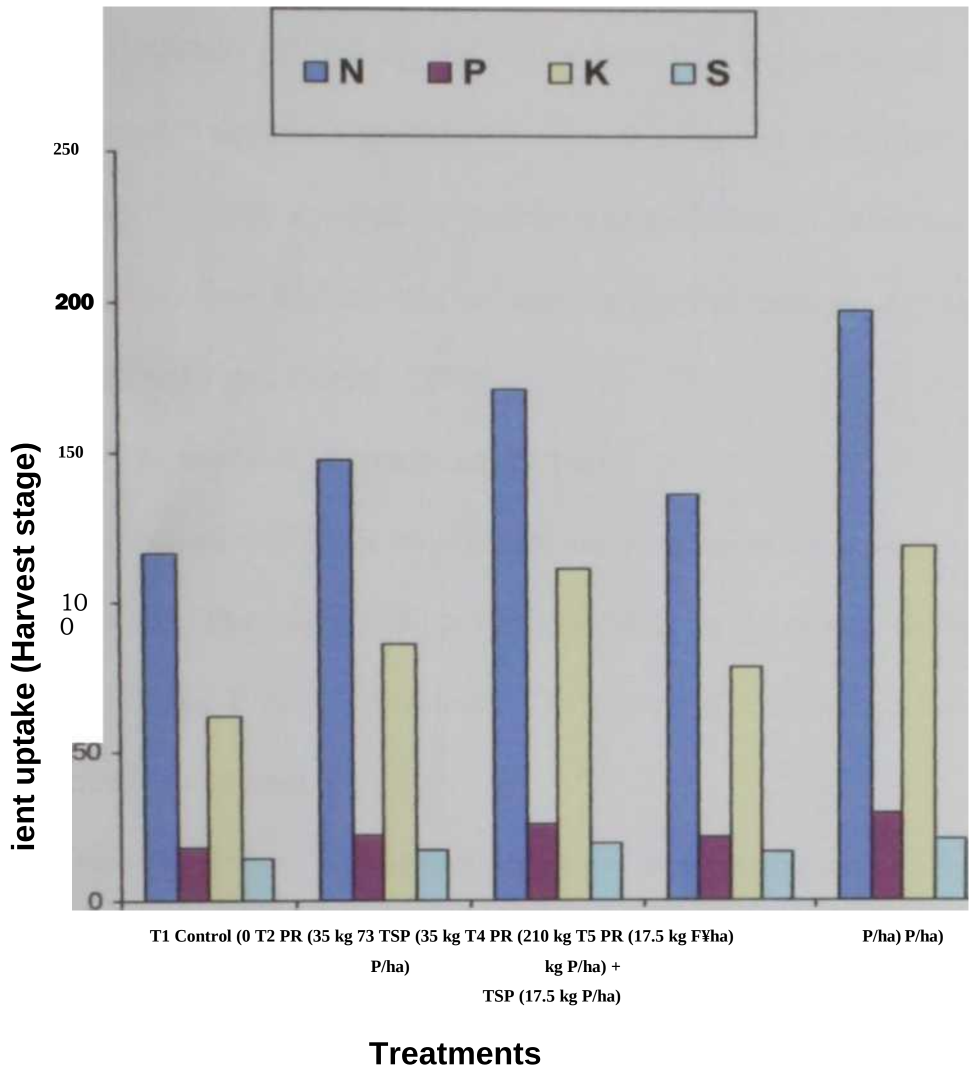


Fig. 6 Effect of differnet treatmens on N, P, K and S uptake by Boro rice at harvest stage

found in T, (control) treatment, which was statistically similar to T> and T_4 treatments. The total P uptake was influenced significantly due to the treatment (Table 10 and Fig.7). The highest total P uptake (29.4 kg ha ') was found in Ts treatment, which was statistically superior to the other treatments except T_3. The second highest total P uptake (25.76 kg ha) was found in T_3 (35 kg P ha'[1] from TSP) treatment. Lowest total P uptake (17.85 kg ha'[1]) was found in T] treatment. The treatments T_3 and T**5** increased P uptake significantly over the control. Full dose of P through PR (T_2) and 210 kg P as PR applied in previous crop failed to increase P uptake significantly. It was found that higher rate of application PR increased P uptake in paddy grain and straw(Datta and Gupta ,1983).

4.1.6.5 K content in grain and straw

The effect of different treatments on K content in grain was statistically significant (Table 11). The highest K content (0.58%) in grain was found T_5 (PR 17.5 kg P ha'[1] + TSP 17.5 kg P ha"[1]) treatment. The lowest K content (0.39%) in grain was found T] (control) treatment.

In case of straw, K content in straw was statistically significant (Table 11). The highest K content (1.11%) was found in T_5 (PR 17.5 kg P ha - TSP 17.5 kg P ha'[1]) treatment which was statistically identical to T:, T_3 and T_4 treatments. The lowest K content (0.61%) was found in Ti (control) treatment.

4.1.6.6 K uptake in grain and straw

The K uptake by grain was found variable due to the effect of different treatments (Table 11). It was observed that K uptake by grain increased with increasing P level.

The highest K uptake (39.78 kg ha^{-1}) by grain was found in T_5 (PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}) treatments which was statistically identical with T_3 treatment.

In case of straw, K uptake varied due to direct application of PR. The uptake in straw ranged from 40.17 to 77.50 kg ha^{-1} (Table 11). The highest K uptake (77.50) was observed in Ts treatment and the lowest K uptake (40.17) w as recorded in T| (control) treatment.

Conclusion may be drawn that phosphorus fertilizer can significantly boost up the K content in grain and straw. Issak (2005) found that K content as well as uptake significantly increased due to mixed application of rock phosphate and triple super phosphate(PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}). P uptake was significantly higher due to inoculation of ***Rhizobium*** and VA-mycorrhiza in presence of organic matter with PR, SSP and their mixture (1:1) P sources (Das ***et al A*** 999).

4.1.6.7 S content in grain and straw

Application of PR and TSP exerted positive effect on S content in grain. The concentration of S in grain ranged from 0.098% to 0.117% (Tablel2). The highest S content (0.0117%) was noted in T? treatment which was statistically identical to T_3 treatment. The lowest S content was noted in control treatments that were statistically similar with T_2, T_3 and T_4 treatments.

Table 11. If feet of different treatments on K concentration and K uptake by Boro ricc (BRRI Dhan 29) at harvest stage

Treatments	Content (%)		Uptake (kg ha^{-1})		Total uptake (kg ha^{-1})
	Crain	Straw	Grain	Straw	
T| Control (0 kg 1' ha ^{1})	0.390c	0.618b	20.67c	40.17d	61.84c
T_2 PR (35 kg P ha^1)	0.525ab	0.800ab	32.03b	52.8c	86.15b
T_3 TSP (35 kg P ha')	0.565a	0.995ab	37.29a	72.33b	111.18a
T_4 PR (210 kg P ha^1) ***	0.465b	0.738ab	29.30b	48.11c	78.61b
T_s PR (17.5 kg P ha^1) + TSP (17.5 kg P ha'^1)	0.585a	1.112a	39.78a	77.50a	118.97a
Level of significance	**	4c 4c	**	**	**
CV%	4.73	9.65	6.74	4.05	4.70

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMR T ***

= Applied in previous crop in 2004 ** = Significant at 1% level of significance

In case of **straw,** S content varied from **0.153%** to **0.174%** (Table **12).** The maximum S content **was** observed in T_5 treatment and the minimum S content was observed in control. Issak **(2005)** reported that S content by rice grain and straw was increased due to mixed application of PR and TSP. S content increased by the grain due to higher rate of application of PR (Rahman, **2005).**

4.1.6.8 S uptake in grain and straw

Results shown in (Table **12)** indicated that S uptake by grain was also significantly influenced by different treatments. The range of S uptake observed in grain was 5.19 to **7.96** kg ha^{-1}. The maximum S uptake **(7.96** kg ha^{-1}) was recorded in T_5 treatment and the lowest value **(5.19** kg ha^{-1}) was recorded in control.

In case of straw, the maximum S uptake was recorded in T_5 treatment and the control treatment obtained minimum S uptake and the range was 9.18 to 13.00 kg ha^{-1}. Application of PR and TSP had significant effect on total S uptake (Tablel2). The highest total S uptake (20.96 kg ha^{-1}) and the lowest total S uptake (14.37 kg ha^{-1}) were recorded in T_5 and control treatment respectively. Islam (2005) stated that S uptake in grain and straw were recorded maximum by the application of PR.

Table 12. Effect of different treatments on S concentration and S uptake by Boro rice (BRRI Dhan 29) at harvest stage

Treatments	Content (%)		Uptake (kg ha'^{1})		Total uptake (kg ha'^{1})
	Grain	Straw	Grain	Straw	
T| Control (0 kg P ha'^{1})	**0.098b**	**0.153b**	**5.19c**	**9.18b**	**14.37c**
T_2 PR (35 kg P ha^{1})	**0.100b**	**0.165ab**	**6.3bc**	**10.89ab**	**17.19bc**
T_3 TSP(35 kg Pha^{1})	**0.105ab**	**0.173a**	**6.93ab**	**12.58a**	**19.5 lab**
T_4 PR (210 kg P ha^{1})* **	**0.100b**	**0.160ab**	**6.1 be**	**10.43ab**	**16.53bc**
T_5 PR (17.5 kg P ha^{1}) + TSP (17.5 kg P ha^{1})	**0.117a**	**0.174a**	**7.96a**	**13.00a**	**20.96a**
Level of significance	*	*	**	**	**
CV%	**7.29**	**5.18**	**10.54**	**10.72**	**9.33**

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT *** =

Applied in previous crop in 2004 ** = Significant at 1% level of significance

* = Significant at 5% level of significance

4.1.7 C haracteristics of the post harvest soils

4.1.7.1 Post harvest soil (0-15cm)

Soil pH

The pH value of initial soil ranged from 5.5 to 6.0 which was statistically non significant. The results (Tablel3) showed that the treatment caused a slight increase in the pH value of the post harvest soils compared to initial soil. The lowest pH value was observed (5.6) in T| treatment and the highest pH value was obtained (6.25) in T_5 treatment.

Organic matter content

Organic matter content of post harvest soil varied significantly by the influence of the effects different treatments. The highest organic matter content (1.06%) was obtained in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha"^{1}) treatment, which was superior to the control treatment. The organic matter content of initial soil was ranged form 0.86 to 0.89. All the treatment had an increasing effect on the organic matter content of post harvest soils compared to initial soil.

Total Nitrogen

Total N content of post harvest soil were not found statistically significant. It was ranged from 0.04 to 0.05% (Table 13). The total N (0.07%) was recorded in T_5 (PR

17.5 kg P ha"^{1} + TSP 17.5 kg P ha"^{1}) treatment. The lowest total N (0.045) in post

17.6 Available Phosphorus

The available P of post harvest soil w as statistically influenced by differen**t**

Table 13. Characteristics of the post harvest soil ((MS cm depth) (boro rice BRRI Dhan-29)

Treatments	pH	Organic matter (%)	Total nitrogen (%)	Available S (ppm)	Available P (ppm)	Exchangeable K (meq 100 g‘ 1 soil)
Ti Control (0 kg I* ha'1)	5.60	0.91b	0.04	21.00d	28.00b	0.12c
T_2 PR (35 kg 1* ha'')	5.80	1,00a	0.05	27.00b	38.12b	0.14b
T_3 TSP (35 kg P ha^1)	6.00	1,04a	0.06	28.00b	40.50ab	0.16a
T_4 PR (210 kg P ha^1)***	5.80	0.90b	0.05	25.00c	35.37b	0.13c
T_5 PR (17.5 kg P ha'1) + TSP (17.5 kg P ha^1)	6.25	1.06a	0.07	30.00a	48.12a	0.17a
Level of significance	NS	**	NS	**	*	**
CV%	3.79	6.29	10.43	8.61	9.42	8.78

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

NS = non significant

***** = Applied in previous crop in 2004**

** = Significant at 1% level of significance
***** = Significant at 5% level of significance

treatments (Table 13). Available P varied from 28.00 ppm to 48.12 ppm. The highest value of available P was obtained (48.12 ppm) in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha ') treatment, which was statically similar to T_3 treatment but statistically significant to T| treatment. The lowest value of P (28.00 ppm) was obtained in *1* j treatment. All the treatments had an increasing effect except T| on the available P of the post harvest soils.

Exchangeable Potassium

The exchangeable K value of the initial soil was 0.1 1 to 0.14 meq 100 g '^{1} soil. The treatments had the significant effects on the exchangeable K of post harvest soils (Table 13). The highest exchangeable K (0.14 meq 100 g'^{1} soil) was obtained in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha'^{1}) treatment, which was superior to other treatment. The lowest value of exchangeable K (0.11 meq 100 g'^{1} soil) was obtained in Ti (control) treatment which was inferior to all treatments.

Available Sulphur

The effect of different treatments on available S of post harvest soil was statistically significant (Table 13). The available S content in initial soil was ranged form **10.43** to 20.18 ppm and values in the post harvest soils varied from 21.00 to 30.00 ppm. The highest value (30.00 ppm) was found in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha'^{1}) treatment, which was statistically significant as compared to all other treatments. The lowest value of available S (21.00 ppm) was found in T, (control) treatment.

4.1.7.2 Post harvest soil (15-30cm)

Table 14 shows the characteristics of the post harvest soils of 15-30 cm depth as influenced by different treatments. Results showed a marked variation in the pH, soil organic matter, N, P, K and S.

pH values of the post harvest soils of 15-30 cm depth ranged from 5.25 to 5.30 The highest pH value (5.30) was recorded in T**5** treatment and lowest pH value (5.25) was recorded in control treatment. The variations of pH value among the treatments were insignificant.

The organic matter content of the post harvest soil (15-30 cm depth) ranged from

0. 71% to 0.94% (Table). The maximum organic matter content (0.94%) was obtained in T_5 treatment and the minimum organic matter content (0.71%) was obtained in the treatment Tp The variations of the organic matter content among the treatments were significant.

The total N content of the post harvest soil (15-30cm) did not vary significantly among the treatment. It ranged from 0.03% to 0.04% (Table). The highest total N content was observed in T_5 treatment which was similar to T_3 and the lowest N content was found in Ti treatment, which was similar to T_2 and T_4 treatments. Application of PR and TSP exerted a significant effect on the available P content in 15-30 cm depth of post harvest soil. The P content in post harvest soils ranged from 21.37 to 32.50 ppm. The highest P content was recorded in the treatment T_5 (32.50ppm) followed by T_3 (31.37 ppm), T_2 (25.62 ppm) and T_4 (24.75 ppm). The lowest P content was found in control.

The K content of post harvest soils (15-30cm depth) ranged from 0.08 to 0.12 meq/l00g soil (Table 14). The highest K content was observed in T_5 treatment.

Table 14. Characteristics of the post harvest soil (15-30 cm depth) (Boro rice BRRI Dhan 29)

Treatments	pH	Organic matter (%)	Total nitrogen (%)	Available S (ppm)	Available P (ppm)	Exchangeable K (meq 100 g$^{'1}$ soil)
Ti Control (0 kg P ha$^{'1}$)	5.25	0.71c	0.03	14.25b	21.37c	0.08b
T_2 PR (35 kg P ha^{1})	5.30	0.81 be	0.03	17.00b	25.62bc	0.1 la
T_3 TSP (35 kg P ha^{1})	5.10	0.83b	0.04	21.50a	31.37ab	0.11a
T_4 PR (210 kg P ha$^{'1}$) ***	4.95	0.75bc	0.03	16.75b	24.75bc	0.10b
T_5 PR (17.5 kg P ha$^{'1}$) + TSP (17.5 kg Pha^{1})	5.30	0.94a	0.04	23.00a	32.50a	0.12a
Level of significance	NS	**	NS		**	**
CV%	2.01	5.85	11.83	8.36	11.22	8.70

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

NS = non significant

*** = Applied in previous crop in 2004

** = Significant at 1% level of significance was statistically identical to T_3 and T_2 treatments and the lowest K content was recorded in T, treatment, which was statistically similar to T_4 treatment Available S content of post harvest soils was influenced significantly due to different treatments (Tablel4). The maximum S content (23.00 ppm) was observed in T**5** treatment which was statistically similar to T_3 treatment and the lowest S content (14.25 ppm) was observed in Tj treatment.

4.1.8 Economic analysis

The analysis was done in order to find out the most profitable treatment based on cost and benefit of various treatments. Net benefit was calculated by subtracting the total input cost from the gross field income. Gross field income was calculated as the total market value of grain and straw of rice. The input cost was calculated as the total market value of fertilizers, and other material and non-material cost. The results of economic analysis of rice (cv. BRRI Dhan 29) showed that the highest net benefit of Tk. 51550 ha'^{1} was obtained in T_5 treatment followed by Tk. 84154 ha ', Tk. 47509 ha'^{1}, Tk. 44199 ha'^{1} and Tk. 37989 ha-^{1} in T_3, T_2, T_4 and T, treatments respectively (Table 14). Supplementing the rock phosphate with superphosphate in acid soils was more economical (Krishnappa ***et al*** 1991). The judicious mixed application of PR and TSP was more effective and beneficial due to its appropriate availability for plants over longer period of time and at comparatively low cost (Issak, 2005).

Table 15. Economics for fertilizer use in crop production under Boro rice (cv. BRRI Dhan 29)

Treatments	Total output (k& la)		Gross field income (Tk ha^{-1})			Total input cost (Tk. ha^{-1})	Net benefit (Tk. ha^{-1})	Net benefit increase over control (%)
	Grain	Stra	Grain	Straw	Total			
T_1. Control (0 kg P ha^{-1})	5300	6000	47700	6000	53700	15711	37989	–
T_2. PR (35 kg p ha^{-1})	6100	6600	54900	6600	61500	17301	47509	25.05
T_3. TSP (35 kg p ha^{-1})	6600	7270	59400	7270	66670	18516	48154	26.76
T_4. PR (210 kg p ha^{-1})	6300	6520	56700	6520	63220	15711	44199	16.37
T_5 PR (17.5 kg P ha^{-1}) + TSP (17.5 kg P ha^{-1})	6800	7470	61200	7470	68670	17120	51550	35.69

Production cost other fertilizer remain same in all treatments.

** Current market prices were used for rice grain, straw, fertilizer are listed value.

Output cost Grain @ 9.00 per kg. Straw @ 1.00 per kg.

Input cost a) Material cost

PR @ 6.00 per kg. TSP («) 16.00 per kg. Urea @ 6.50 per kg. MOP @ 16.00 per kg. Zypsum @ 6.50 per kg ZnO @ 70.00 per kg. Irrigation - 3000.00 Tk. Pesticide- 1500.00 Tk. Seed- 300 Tk.

b) Non-material cost Labour cost- 4900 Tk. Ploughing- 2000 Tk.

4.2. Residual crop (T. aman rice cv. BRRI Dhan 30)

4.2.1. Dry matter yield

After harvest of the first crop a residual crop (T. aman rice cv. BRRI Dhan 30) was grown to see the residual effect of PR and TSP of different treatments. The dry matter yield of T. aman rice was determined at the time of maximum tillering and panicle initiation stages while grain and straw yield were recorded at maturity.

4.2.1.1. Dry matter yield at maximum tillering stage

The residual effect of different treatments on dry matter yield of rice at maximum tillering stage was significant (Tablel**6**). Highest dry matter yield (2.67 t ha^{1}) was obtained in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha'^{1}) treatment, which was similar with T_3 treatment. The low est dry matter yield (2.17 t ha) was found in T| treatment, which was similar to T_2 and T_4 treatments. Dry matter yield increased over control (T,) by 16.85% under the treatment T_5. Dry matter yield was increased due to higher rate of application of PR. Attanandana and Vacharotyan (1984) compared rock phosphate (PR) with triple super phosphate (TSP) on nee growth and yield in pots in the acid sulphate soils. They found that higher rates of liming reduced P availability from PR. According to them PR gave the best residual effect.

Table 16. Residual effect of different treatments on dry matter yield at maximum tillering (MT) stage and panicle initiation (1*1) stage of rice (BRRI Dhan 30)

Treatments	A(M l stage Dry matter Yield (t ha ')	At IM stage Dry matter Yield (t ha-') _ _
T| Control (0 kg 1* ha'^{1})	2.17b	3.68c
T_2 PR (35 kg P ha^{1})	2.28b	4.32abc
Tj TSP (35 kg P ha'^{1})	2.33ab	4.6 lab
T_4 PR (210 kg P ha'^{1}) ***	2.22b	4.01 be
Ts PR (17.5 kg P ha'^{1}) + TSP (17.5 kg P ha'^{1})	2.67a	4.82a
Level of significance	**	**
CV%	10.19	7.85

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT *** =

Applied in previous crop in 2004 ** = Significant at 1% level of significance

T1 Control (0 T2 PR (35 kg T3 TSP (35 kg T4 PR (210 kg T5 PR (17.5 kg kg P/ha) P/ha) P/ha)

P/ha) P/ha) + TSP

T reatments <175 ks p/ha)

Fig. 7 Effect of differnet treatmens on dry matter yield at maximum tillering (MT) stage of T. a man rice

T1 Control (0 T2 PR (35 kg T3 TSP (35 kg T4 PR (210 kg T5 PR (17 5 kg ka P/ha) P/ha)
P/ha) P/ha) P/ha) + TSP
(17 5 kg P/ha)

Treatments

Fig. 8 Effect of diffemet treatmens on dry matter yield at panicle initiation (PI) stage of T. aman rice

1. Dry matter yield at panicle initiation (PI) stage

The residual effect of different treatments on dry matter yield of rice at panicle initiation stage was also significant (Tablel**6**). The dry matter yield of rice under the treatments ranged from 3.68 t ha ^{1} to 4.82 t ha*^{1}. The highest dry matter yield was 4.82 t ha'^{1} was obtained in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha'^{1}) treatment, which was similar to T**3** treatment. The lowest dry matter yield (3.68 t ha) was recorded in T! treatment, which was statistically similar to T**2** and T_4 treatments.

4.2.2 Yield and yield contributing characters

4.2.2.1. Plant height

The different treatments produced non significant effect on plant height of succeeding T.aman rice(Tablel7). It was found that plant height in different treatments observed ranged from 99.66cm to 103.89 cm. The highest plant height was found T_5 treatment. The lowest plant height (99.66cm) was found in Ti treatment.

4.2.2.2 Total tillers hill^{-1}

The residual effect of different treatments on total tillers hill" was statistically significant. The maximum number of tiller hill'^{1} (12.05) was obtained in T_5 (PR 17 **5** k^{a} P ha'^{1} + TSP 17.5 kg P ha ') treatment which was statically similar to the treatments of T_2 and T_3. In producing total number of tillers hill the residual effects of different treatments may be arranged as T_5> T_3> T_2> T_4> T,.

4.2.2.3 Effective tillers hill^{1}

Combined applicatt, on of PR & TSP (T_5) in the previous crop increased effective tillers per hill significantly over other treatments (Table 17). The maximum number of effective tillers hill^{1} (9.60) were obtained in T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha ') treatment. The lowest number of effective tillers hill'^{1} (8.00) were obtained in Tj (control) treatment. The effects of judicious application of PR and TSP increased effective tillers hill *. Rahman (2005) stated that higher rate of application of rock phosphate significantly increased the effective tillers hill'^{1}.

4.2.2.4 Panicle length

Panicle length was not influenced significantly although there was some apparent difference in panicle length in different fertilizer treatments over control (Table 17). Maximum panicle length (26.38 cm) was attained in T_5 treatment and minimum panicle length (24.96 cm) was attained in treatment T_4.

4.2.2.5 Unfilled grains panicle ^{1}

Table 17 shows the residual effects of different treatments on unfilled grains panicle'^{1}. It was found that unfilled grains panicle'^{1} to be statistically significant. The highest unfilled grains (28.57) obtained in T, (control) treatment which was statistically identical to T_2 (PR 35 kg P ha'^{1}) and T_4 (PR 210 kg P ha'^{1}) and lowest unfilled grains (21.33) was obtained T**5** (PR 17.5 kg P ha ^ TSP 17.5 kg P ha) treatment. It was observed that the judicious application of PR and TSP decreased unfilled grains panicle'^{1}. However, the percentage of unfilled grains panicle ranged from 20.04 to 27.88. Lowest percent of unfilled grains was recorded in the T_5 treatment which was superior to other treatments.

4.2.2.6 Filled grains panicle ^{1}

The filled grains panicle ^{1} varied significantly among the treatments (Tablel7). The highest number of filled grains panicle ^{1} (85.11) was obtained in the treatment T**5** (PR 17.5 kg P ha + TSP 17.5 kg P ha '), which was statically similar to T_2, T**3** and T_4 treatments. The lowest filled grains panicle'^{1} (73.90) was obtained in treatment T| (control P_0). It was observed that filled grains panicle'^{1} increased due to combined application of PR and TSP. All the treatments may be arranged according to their superiority as T_5>T**3**>T_2>T_4>T|. Rajkhowa ***et al*** (1998) reported that the filled grains panicle'^{1} increased with increasing P rate as a mixture of URP and Superphosphate (1:1 ratio) up to a plateau at 38.7 kg ha^{1}. However, the percentage of filled grains panicle'^{1} ranged from 72.07 to 79.96.1 he highest percent of filled grians (79.96) was found of T_5 treatment, which was statically similer to T_2 and T_3 treatments. The lowest percent of filled grains was recorded in the T**1** treatment.

Table 17. Residual effect of different treatments on yield contributing characters of T. aman rice (BRRI Dhan 30) at harvest

Treatments	Plant height (cm)	Total tillers hill^{1} (No.)	Effective tillers hill'^{1} (No.)	Panicle length (cm)	Unfilled grain panicle ^{1} (No.)	Percent unfilled grain	Filled grains panicle ^{1} (No.)	Percent filled grain	1000-grain weight (g)
T| Control (0 kg P ha ^{1})	99.66a	10.00b	8.00b	25.50a	28.57a	27.88a	73.90b	72.07c	22.35a
T_2 PR (35 kg P ha'^{1})	102.79a	10.75ab	8.85ab	25.49a	24.16abc	23.17abc	82.91a	77.24ab	22.75a
T_3 TSP (35 kg Pha')	103.49a	11.15 ab	9.20a	25.51a	22.16bc	20.96bc	84.70a	78.30ab	22.92a
T_4 PR (210 kg P ha'^{1}) ***	101.01a	10.50b	8.50ab	24.96a	26.95ab	25.18ab	80.06ab	74.82bc	22.80a
T_5 PR (17.5 kg P ha^{1}) + TSP (17.5 kg P ha^{1})	103.89a	12.05a	9.60a	26.38a	21.33c	20.04c	85.11a	79.96a	23.55a
Level of significance	NS	*	*	NS	*	♦ ♦	♦ ♦	*	NS
CV%	5.18	7.80	7.68	8.16	12.83	8.96	4.68	4.03	5.84

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

NS = Non significant

*** = Applied in previous crop in 2004

** = Significant at 1% level of significance

* = Significant at 5% level of significance

4.2.3 Yield 4.2.3.1

Grain yield

The residual effects of different treatments on grain yield of T. ***aman*** rice (cv. BRRI dhan 30) reveals a significant variation (Table 18). The grain yield varied from 3.06 to 4.51 t ha . The maximum yield (4.51 t ha'[1]) was noted in treatment T_5 (PR 17.5 kg P ha + TSP 17.5 kg P ha ') which was statistically significant to other treatments. The lowest grain yield was (3.06 t ha ') obtained in T| (control Po) treatment. The second highest yield (4.26 t ha'[1]) was obtained in treatment T**3** (PR 35 kg P ha ') which was statically similar to T_5 treatment. In producing grain yield, the treatment may be ranked in order of T_5> T_3> T_2> T_4> Tj. (Shown in Fig 9). Sara Sawudyotin (1987) reported that rock phosphate was more effective than TSP for the unlimed treatment. The grain yield in the rock phosphate treatment was five times the TSP application. The residual effect of rock phosphate was superior to TSP in terms of grain producing without liming. The grain yield was **20**% higher in the rock phosphate application.

4.2.3.2 Straw yield

The residual effect of different treatments on the straw yield of rice was markedly influenced which is given in Table. The highest straw yield (5.30 t ha[1]) was recorded in T_5 (PR 17.5 kg P ha**[1]** + TSP 17.5 kg P ha[1]) treatment which was statistically similar to T,, T_3 andT_4 treatments. (Table 18 and Fig.9). It was found that straw yield of rice was increased due to mixed application of PR and TSP.

Thongbai ***et al.*** (1988) reported that PR increased rice yield over control. Misra ***et** al* (2002) found that application of modified PRs significantly increased dry matter yield by the crops. Das et ***al*** (1999) also reported that the dry matter yield was significantly increase due to mixed application of RP and SSP(1:1 ratio). Similar observ ations were also found many researchers.

4.2.4 P content in grain and straw

The P content in grain and straw was significantly affected by the residual effects of different treatments. The content of phosphorus in grain ranged from 0.13% to 0.21% (Table). The maximum P content (0.21 %) was attained in T_5 treatment which was similar to T3 treatment. The minimum P content was obtained in control treatment. Significant increase in P content as well as uptake with the application of TSP with PR was in corroboration with the findings of BRRI (1978) and Hammond ***et al.*** (1986). Islam (2005) also reported that P content in grain and straw were maximum by the application of PR.

The highest P content in straw was attained in T_5 treatment (0.08° o) which was statistically similar to the treatments of T_2, T_3 and T_4. The minimum content was observed in control treatment. However, in case of straw, TSP had shown similar effect over PR having the same rate of P (35 kg $ha^{'1}$).

4.2.4.1 P uptake in grain and straw

Like P content, P uptake by grain and straw was influenced significantly due to different treatments. However, maximum P uptake by grain was recorded in T**5** treatment minimum was in control. Application of TSP & PR (1:1 ratio) had shown better effect than other treatments. Incase of straw the maximum P uptake was (4.67 kg ha ') in T_5 treatment and minimum was (2.55 kg ha ^{1}) in control. The total uptake range varied from 6.53 to 14.37 kg ha'^{1}. Islam (2005) also reported that P content and uptake significantly increased due to the application of PR and TSP.

4.2.5 Characteristics of the post harvest soils

Table 20 revealed the characteristics of the post harvest soils as influenced by different treatments. Results showed a marked variation on the pH, soil organic matter, N, P, K and S of the initial soil values.

pH values of the post harvest soils ranged from 5.60 to 6.10. The highest pH value (6.10) was recorded in T_5 treatment and lowest pH value (5.60) was recorded in control treatment. The variations in pH value among the treatments were insignificant.

The organic matter content of the post harvest soil ranged from 1.11% to 1.26% (Table). The maximum organic matter content (1.26%) was obtained in T_5 treatment and the minimum organic matter content (**1.11**%) was obtained in the treatment T_1.

Tabic 18. Residual effect of different treatments on grain and straw yields of rice (BRRI Dhan 30)

Treatments	Grain Yield (t ha'^{1})	Straw Yield (t ha'^{1})
Ti Control (0 kg P ha^{1})	3.265b	4.010b
T_2 PR (35 kg Pha^{1})	3.950ab	4.650a
T_3 TSP (35 kg P ha'^{1})	4.260a	4.860a
T_4 PR (210 kg P ha'^{1}) ***	3.740ab	4.550a
T_5 PR (17.5 kg P ha'^{1}) + TSP (17.5 kg P ha'^{1})	4.513a	4.800a
Level of significance	*	*
CV%	12.41	7.22

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

*** = Applied in previous crop in 2004

* = Significant at 5% level of significance

□ Grain yield

■ Straw yield

6

Grain and Straw yield (t/ha)

2 -

T1 Control (0 T2 PR (35 kg T3 TSP (35 kg T4 PR (210 kg T5 PR (17 5 kg kg P/ha) P/ha) P/ha)

P/ha) P/ha) -*• TSP

(17.5 kg P/ha)

Treatments

Fig. 9 Effect of diffemet treatmens on grain and straw yield of T. aman rice

Table 19. Residual Effect of different treatments on I* concentration and I* uptake by T. aman rice (BRRI Dhan 30) at harvest stage

Treatments	Content (%)		Uptake (kg ha $^{-1}$)		Total uptake (kg ha ')
	Grain	Straw	Grain	Straw	
T| Control (0 kg P ha ^{1})	0.13c	0.067b	3.98c	2.55c	6.53d
T_2 PR (35 kg P ha^{1})	0.15b	0.083ab	6.12c	3.86b	9.98c
T_3 TSP (35 kg P ha'^{1})	0.20a	0.088a	8.52b	4.28ab	12.8b
T_4 PR (210 kg P ha^{1})***	0.13bc	0.080ab	5.05d	3.64b	8.69c
T_5 PR (17.5 kg P ha'^{1}) + TSP (17.5 kg P ha')	0.21a	0.088a	9.70a	4.67a	14.37a
Level of significance	**	*	**	**	**
CV %	9.47	10.08	7.27	8.12	6.06

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

*** = Applied in previous crop in 2004 ** = Significant at 1% level of significance

* = Significant at 5% level of significance

The total N content of the post harvest soil ranged from 0.05% to 0.06% (Table).

The highest total N content was observed in T_s treatment. The lowest total N content was found in treatment T,.

Available S content of post harvest soils influenced significantly due to different treatments (Table 20). The maximum S content (25.25ppm) was observed in T_5 treatment and the lowest S content (11.25 ppm) was observed in control treatment.

Application of PR and TSP exerted significant effect on the available P content in post harvest soil. The P content in post harvest soils ranged from 25.25 to 51.5 ppm. The highest P content was recorded in the treatment T_5 (51.5 ppm) which was statistically similar to T_2, T_3 and T_4 treatments.

The K content of post harvest soils ranged from 0.11 to 0.15 meq/l00g soil (Table 20). The highest K content was observed in T_5 treatment which was statistically identical to T_2 and T_3 treatments and the lowest K content was recorded in Treatment.

4.2.6 Economic analysis

The analysis was done in order to find out the most profitable treatment based on cost and benefit of various treatments. Net benefit was calculated by subtracting the total input cost from the gross field income. Gross field income was calculated as the total market value of grain and straw of rice. The input cost was calculated as

Table 20. Residual characteristics of the post harvest soil (T. aman rice cv. BRRI Dhan 30)

Treatments	pH	Organic matter (%)	Total nitrogen (%)	Available S (ppm)	Available P (PP^{m})	Exchangeable K(meq 100 g'soil)
T| Control (0 kg P ha"^{1})	5.60	1.11b	0.058	11.25c	25.25b	0.11c
T_2 PR (35 kg Pha'^{1})	5.75	1.20a	0.065	18.25b	36.50a	0.13abc
T_3 TSP (35 kg Pha^{1})	5.90	1.26a	0.067	19.75b	42.75a	0.14ab
T_4 PR (210 kg P ha'^{1}) ***	5.80	1.13b	0.060	16.75b	45.00a	0.12bc
T_s PR (17.5 kg P ha^{1}) + TSP (17.5 kg P ha'^{1})	6.10	1.26a	0.068	25.25a	51.62a	0.15a
Level of significance	NS	**	NS	♦ ♦		**
CV%	2.01	3.07	2.99	8.78	9.86	8.63

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

*** = Applied in previous crop in 2004 ** = Significant at 1% level of significance

* = Significant at 5% level of significance

the total market value of fertilizers, and other material and non-material eost. The results of economic analysis of rice (cv. BRRJ Dhan 30) showed that the highest net benefit of Tk. 33977 ha^{1} was obtained in T_5 treatment followed by Tk. 31260 ha'^{1}, Tk. 28260 ha ', Tk.26270 ha ' and Tk. 19455 ha'^{1} in Tj, T_2, T_4 and T, treatments respectively (Table **21**). Supplementing the rock phosphate with superphosphate in acid soils was more economical (Krishnappa ***et al*** 1991).

Table 21. Residual economics for fertilizer use in crop production under Boro rice (cv. BRRI Dhan 30)

Treatments	Total output (kg ha)		Gross field income (Tk ha^{1})			Total input cost (Tk. ha'^{1})	Net benefit (Tk. ha’^{1})	Net benefit increase over control (%)
	Grain	Straw	Grain	Straw	Total			
Tj. Control (0 kg P ha’^{1})	3065	3810	27585	3810	31395	11940	19455	–
T_2. PR (35 kg pha^{1})	3950	4650	35550	4650	40200	11940	28260	45.26
T_3. TSP (35 kg p ha’^{1})	4260	4860	38340	4860	43200	11940	31260	60.68
T_4. PR (210 kg pha^{1})	3740	4550	33660	4550	38210	11940	26270	35.03
T_s PR (17.5 kg P ha'^{1}) + TSP (17.5 kg Pha’^{1})	4513	5300	40617	5300	45917	11940	33977	74.64

* Production cost other fertilizer remain same in all treatments.

** Current market prices were used for rice grain, straw, fertilizer are listed value.

Output cost
grain @ 9.00 per kg.
Straw @ 1.00 per kg.

Input cost
a) Material cost
PR @ 6.00 per kg.
TSP (ci} 16.00 per kg.
Urea (al 6.50 per kg.
MOP (a), 16.00 per kg.
Zypsum @ 6.50 per kg ZnO @ 70.00 per kg.
Irrigation - 2000.00 Tk.
Pesticide- 1500.00 Tk.
Seed- 300 Tk.

b) Non-material cost Labour cost-4900 Tk. Ploughing-2200 Tk.

Chapter V

SUMMARY AND CONCLUSION

Two field experiment were conducted in the same plot in two different cropping season at the Sher-e-Bangla Agricultural University (SAU) Research Field, Dhaka, during Boro and T. aman season in 2005 to study the direct and residual effect of Phosphate Rock on soil nutrient status and crop productivity in rice—rice cropping sequence under Modhuput Tract (AEZ 28).

Five treatments were imposed in both experiments. The trail was laid out in Randomized Complete Block Design (RCBD) with four replications. The treatments used were T^ control (0 kg P ha^{1}), T_2: PR (35 kg P ha'^{1}), T_3: TSP (35 kg P ha^{1}), T_4: PR (210 kg P ha'^{1}) applied for previous crop and T_5 PR (17.5 kg P ha^{1}) + TSP (17.5 kg P ha').

The seedling of 40 days (Main crop) and 35 days (Residual crop) old were transplanted in the experimental plots on 13th February', 2005 and **6**th July, 2005. Three seedling were transplanted in each hill. Irrigation, weeding and pesticide application were done as needed. The main crop was harvested at maturity on 30th May and residual crop was harvested on 29th October, 2005. At the maximum tillering and panicle initiation stages, plant samples **(10** hills randomly selected) were collected from each plot for estimating the soil nutrient status and crop productivity by analysis of nutrient content and their uptake. The plant characters were recorded on each plot after final harvest. The studies included growth, yield and yield contributing characters, mineral composition of rice plants at MT, PI and harvesting stages as well as cost benefit studies. Just before harvest, 10 hills were randomly selected from each plot and cut at soil surface and brought to the laboratory to study yield contributing characters of rice. Grain and straw' yield w ere recorded after harvest at 14% moisture content. Grain and straw sample from each plot were chemically analyzed for N, P, K and S. The post harvest soil sample were also analyzed for organic matter content, total N, available P, and exchangeable K, available S and pH. The collected data were analyzed statistically following Duncan’s Multiple Range Test (DMRT).

Dry matter yield was significantly influenced in both crops (PI stage of main crop and both stages of residual crop). Grain and straw yield were significantly influenced both crops due to addition of PR and TSP. Yield contributing characters, like plant height and panicle length were not significantly influenced but other characters like total tiller hill^{1}, effective tiller hill^{1}, field grain panicle ‘, unfilled grain panicle'^{1} and their percent were significantly influenced by direct application and residual effect of PR.

In case of main crop, the effect of different treatments at maximum tillering stages showed increased dry' matter yield of rice over control. The highest (2.70 t ha^{1}) and lowest (2.09 t ha'^{1}) dry matter yields were obtained in T_5 and T, treatments, respectively at maximum tillering stage. At panicle initiation stage the highest

(5.93 t ha ') and the lowest (4.86 t ha ') dry matter yield was obtained in T, and T, treatments, respectively.

y contributing characters were improved more or less due to application of different treatments o\er control. T5 treatment appeared to have produced the maximum number of effective tillers (11.40 hill^{1}) and the minimum number of effective tillers (9.37 hill) was found in control. The maximum number of filled grains panicle (130.63) was recorded in T5 treatment while the lowest value (110.50) was in control. The weight of 1000 grains varied from 19.50 to 20.60g and had no significant difference.

The maximum grain yield (6.80 t ha'^{1}) was attained in T_5 treatment. The second highest grain yield was obtained in T_3 treatment (5.8 t ha^{1}) followed by T_4 (6.30 t ha^{1}), T_2 (6.10 t ha'^{1}) and control (5.30 t ha '). Straw yield of rice plants followed very similar pattern as that of grain. The maximum straw yield (7.47 t ha'^{1}) was obtained in T_5 treatment and the lowest value (6.5 t ha'^{1}) was obtained in control.

N, P, K and S content as well as uptake had significant variation at maximum tillering stage. The maximum N, P, K and S content as well as uptake were attained in T_5 treatment and the lowest value was observed in control. The nutrient content as well as uptake at panicle initiation stage followed very similar pattern as that of maximum tillering stage, although S content was found statistically similar. The highest N, P, K and S contents (3.20%, 0.24%, 2.57% and 0.17%

respectively) were recorded in T_5 treatment and similarly highest N, P, K and S

uptake (86.40 kg ha ^{1} 6.48 kg ha$'^{1}$, 69.44 kg ha ', 4.80 kg ha^{1}, respectively) were recorded in T5 treatment.

P fertilization significantly increased the concentration as well as uptake of all the nutrients (N, P, K and S) over control. The nutrient of grains analyzed revealed that the percent of N, P, K and S varied from 0.98 to 1.36, 0.15 to 0.20, 0.39 to 0.58 and 0.09 to 0.11, respectively and the nutrient uptake of grain analyzed revealed that the amount of N, P, K and S varied from 56.95 to 86.12 kg ha$'^{1}$, 7.95 to 13.94 kg ha^{1}, 20.67 to 39.78 kg ha$'^{1}$, 5.19 to 7.96 kg ha$'^{1}$ respectively. The nutrient content as well as uptake by straw followed the similar trend as that of grain. In all the cases, the highest value was attained in T_5 and the lowest value was attained in control treatment. P applied in the form of combination of PR and TSP was found better over other treatments. This is because, TSP is more soluble than PR and firstly P released from soluble P source (TSP) than PR.

Application of PR and TSP showed considerable influence on the properties of the post harvest soils such as pH, OM, total N, available S, available P and exchangeable K. The pH value of post harvest soils (0-15 cm depth) range varied from 5.60 to 6.25. All the treatments recorded higher pH value as compared to the initial soil. The organic matter content of the post harvest soils (0-15 cm depth) ranged from 0.91 to 1.06. The N, P, K and S content of the post harvest soils(0-15 cm depth) ranged from 0.04 to 0.07%, 28.00 to 48.12 ppm, 0.12 to 0.17 meq 100 g-1 soil and 21.00 to 30.00 ppm, respectively. The highest N, P, K and S content was recorded in **T_5** treatment.

pH value of post harvest soils (15-30 cm depth) range varied from 5.25 to 5.30. The organic matter content of the post harvest soils (15-30 cm depth) ranged from 0.71 to 0.94. The N, P, K and S content of the post harvest soils(15-30 cm depth) ranged from 0.03 to 0.04%, 21.37 to 32.50 ppm, 0.08 to 0.12 meq 100 g'**1** soil and 14.25 to 23.00 ppm, respectively. The highest N, P, K and S content was recorded in T_5 treatment. But N, P, K, S, organic matter content and pH (15-30 cm depth soil) value comparatively lower than the 0-15 cm (surface soil).

The results of economic analysis showed that the highest net benefit of Tk.51550 ha'**1** was obtained in T_5 treatment and the lowest net benefit of Tk.37989 ha'**1** was found in control.

In case of residual crop, the effect of different treatments at MT stage showed increased dry matter yield of rice over control. The highest (2.67 t ha ‘) and lowest (2.17 t ha'1) dry matter yield at MT stage was recorded in T_5 and T| treatments, respectively. At PI stage, maximum (4.82 t ha) and minimum (3.68 t ha !) dry matter yield were obtained in T_5 and T, treatments, respectively.

All yield contributing characters were improved more or less due to application of different treatments over control. T_5 treatment appeared to have produced the maximum number of effective tillers (9.60 hill*1) and the minimum number of effective tillers (8.00 hill ') was found in control. The maximum number of filled grains panicle-' (85.11) was recorded in T_5 treatment while the lowest value (73.90) was in control. The weight of 1000 grains varied from **22.35** to 23.55g and had no significant difference.

The maximum grain yield (4.51 t ha'[1]) was attained in T_5 treatment. The second highest grain yield was obtained in T_3 treatment (4.26 t ha ') followed by T_2 (3.95 t ha), T_4 (3.74 t ha ') and control (3.26 t ha '). Straw yield of rice plants followed very similar pattern as that of grain. The maximum straw yield (4.80 t ha[1]) was obtained in T_s treatment and the lowest value (4.01 t ha[1]) was obtained in control.

P fertilization significantly increased the concentration as well as uptake of P over control. The nutrient of grains analyzed revealed that the percent of P varied from 0.13% to **0**.**21**% and the nutrient uptake of grain analyzed revealed that the amount of P varied from 3.98 to 9.70 kg ha'[1]. The nutrient content as well as uptake by straw followed the similar trend as that of grain. In all the cases, the highest value was attained in T**5** and the lowest value was attained in control treatment. P applied in the form of combination of PR and TSP was found better over other treatments. This is because, TSP is more soluble than PR and firstly P released from soluble P source (TSP) than PR. Application of PR and TSP showed considerable influence on the properties of the post harvest soils such as pH, OM, toial N, available S, available P and exchangeable K. The pH value of post harvest soils range varied from 5.60 to **6.10**. The organic matter content of the post harvest soils ranged from **1.11** to 1.26. The N, P, K and S content of the post harvest soils ranged from 0.05 to 0.06%, 25.25 to 51.62 ppm, 0.11 to 0.15 meq 100 g^{1} soil and 11.25 to 25.25 ppm, respectively. The highest N, P, K and S content was recorded in T**5** treatment.

The results of economic analysis showed that the highest net benefit of Tk.33977 ha was obtained in T**5** treatment and the lowest net benefit of Tk. 19455 ha'^{1} was found in control.

It may be concluded that PR will entirely be a new source of P fertilizer to be used in Bangladesh. Present work in the same plot in two different cropping seasons with first crop as BRRI Dhan 29 and residual crop as BRRI Dhan 30 in the trial with PR. Indicated that T_5 (PR 17.5 kg P ha'^{1} + TSP 17.5 kg P ha'^{1}) as well as T_3 (TSP 35 kg P ha'^{1}) showed better performance. Among these two treatments T_5 is comparatively economic to the farmers. But treatment T_4 with higher rate of P (PR 210 kg P ha'^{1}) that applied at a time in previous crops had a little residual effect.

The overall result shows that TSP gives better performance but combined application of phosphate rock (PR) and TSP had a positive effect on rice production in Bangladesh as a new fertilizer for P source. Although PR add some toxic substance in soil its low price and hiah residual effect on subsequent crops it could be an added factor for easy acceptance of PR as P fertilizer than other phosohatic fertilizer.

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Appendix I: Average temperature, humidity and rainfall data during January to June, 2005 (Site-Dhaka)

Month	Relative Humidity (%)	Maximum Temperature (°C)	Minimum temperature (°C)	Rainfall (mm)
January	62.2	32.1	22.1	-
February	63.45	32.2	21.3	-
March	61.55	33.5	20.2	-
April	66.5	34.4	24.1	91
May	74.60	33.2	24.2	298
June	78.60	33.4	26.8	260

* = Monthly total ** = Monthly average

Source: Bangladesh Meteorological Department (Climate Division), Agargon, Dhaka- 1212.

Appendix II: Average temperature, humidity and rainfall data during July to December, 2005 (Site-Dhaka)

Month	Relative Humidity' (%)	Maximum Temperature (°C)	Minimum temperature (°C)	Rainfall (mm)
July	80.78	31.1	26.1	542
August	83.22	32.0	26.7	361
September	81.71	31.7	26.0	514
October	88.42	30.6	23.3	413
November	73.90	29.0	19.8	03
December	62.79	27.0	15.7	00

* = Monthly total ** = Monthly average

Source: Bangladesh Meteorological Department (Climate Division), Agargon, Dhaka- 1212.

Appendix III: Available P_2O_5 (%) from different sources of fertilizer

sources of fertilizer	Available P205 (%)
Rock Phosphate (PR)	**25-40**
Triple super phosphate (TSP)	**44-52**

Source: Bangladesh Fertilizer Association (BFA), City heard 10^{Ih} Floor, Room # 8, 67, Nayapalton, Dhaka-1000.