INFLUENCE OF DIRECT APPLICATION OF ROCK PHOSPHATE ON GROWTH, YIELD AND NUTRIENT UPTAKE OF RICE (BRRI DHAN 39) IN AN ACID SOIL

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2005

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By

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REGISTRATION NO. 01503

A Thesis

Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE

Semester : July – December,2005

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CERTIFICATE

This is to certify that thesis entitled, "*INFLUENCE OF DIRECT APPLICATION OF ROCK PHOSPHATE ON GROWTH, YIELD AND NUTRIENT UPTAKE OF RICE(BRRI DHAN 39) IN AN ACID SOIL*" Submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE (M.S.)* in *SOIL SCIENCE* embodies the result of a piece of *bona fide* research work carried out by *MOHAMMAD ISSAK* Registration No. **01503** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: ……………………………..

Place**: Dhaka, Bangladesh** **Supervisor**

Dr. Gopi Nath Chandra Sutradhare

ACKNOWLEDGEMENT

Alhamdulillah. Allah, the merciful, who has created everything in this universe and kindly enabled me to present this thesis for the degree of Master of Science (M.S.) in Soil Science.

I express my sincere gratitude, hearty respect, immense indebtedness and profound appreciation to my research supervisor Associate Professor Dr. Gopi Nath Chandra Sutradhar, Chairman, Department of Soil Science, Shere-e-Bangla Agricultural university (SAU), Dhaka for his scholastic guidance and immense help in preparing the thesis.

I express my deepest sense of respect, gratitude and profound indebtedness to my reverend co-supervisor Md. Mukhlesure Rahman, Chief Scientific Officer (CSO), Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur for his constant cooperation, constructive criticism and technical help.

I feel to express my sincere appreciation and indeptedness to my esteemed teachers Professor Dr. Md. Nurul Islam, Associate Professor Dr. Alok Kumer Paul, Assistant Professors A. T. M. Shamsuddoha, Md. Asaduzzaman Khan and Mst. Afrose Jahan and Lecturer Md. Mosharraf Hossain, Dept. of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, direct and indirect advice, encouragement and cooperation during the whole study period.

I owe special gratitude and feel highly esteemed to place sincere thanks to the Vice – Chancellor Prof. Dr. A. M. Farooque, Registrar Mr. Abu Akbar Mia and Post Graduate Dean Prof. Md. Shadat Ulla for helping me in several ways. I do also wish to express my cordial thanks to Dr. Syed Anwarul Haque for the supply of Rock Phosphate fertilizer and other technical help.

I owe a lot to Dr. Parimal Kanti Biswas, Dr. A. K. M. Ruhul Amin, Dr. M. A. Hashem and Dr. Md. Rafiqul Islam for their help just when I needed.

I expresses my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my mother Mrs. Zohura Begum, father Md. Abul Hashem, and also pleasant to my brother Md. Nural Islam and sisters, Poly, Joly and Doly whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of my higher study.

I feel much pleasure to convey the profound thanks to my friends, well wishers for their active encouragement and inspiration; personal acknowledgement are made to Tuhin, Zakir, Titu, Saiful, Prince, Rasomoi, Samima, Firdousi, Rouf, Ratan,Khairul, Sanjoy, Sanjit, Prodip, sraban and Khokon.

Mohammad Issak

Place: Dhaka

Dated: th December,2005

ABSTRACT

A field experiment was carried out in Modhupur Tract (AEZ 28) at Agronomy Field Laboratory in Sher-e-Bangla Agricultural University, Dhaka to study the influence of direct application of rock phosphate (PR) in comparison to TSP as a source of P on growth, yield and nutrient uptake of BRRI Dhan 39 during the T. aman season, 2004. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications of each treatment. The treatments used were T_1: control (0 kg P ha^{-1}), T_2: PR (35 kg P ha^{-1}), T_3: TSP (35 kg P ha^{-1}) and T_4: PR (210 kg P ha^{-1}), T_5: TSP (17.5 kg P ha^{-1}) + (PR 17.5 kg P ha^{-1}). Basal application was made with N, K, S and Zn. The results indicated that there was no statistical difference in dry matter yield at maximum tillering stage, but the dry matter production at panicle initiation stage was found statistically significant. Among the yield and yield contributing characters effective tillers $hill^{-1}$, filled grains $panicle^{-1}$, unfilled grain $panicle^{-1}$, grain yield and straw yield were significantly varied with P treatments. The highest grain yield was recorded in T_5 treatment and the lowest yield in control treatment. The yields due to different treatments ranked in the order of T_5>T_4> T_3> T_2> T_1. The N, P, K and S contents as well as uptake by rice plant were also increased due to application of different treatments. The maximum N, P, K and S content as well as uptake in rice plant, grain and straw were recorded in T_5 treatment. The economic analysis demonstrated that the highest net benefit of Tk. 25165 ha^{-1} was obtained in T_5 treatment. The N, P, K and S nutrient contents and uptake significantly increased due to mixed (1:1 ratio of T_2 and T_3 treatments) application of rock phosphate (PR) and Triple Super Phosphate (TSP) in T_5 treatment compared to other treatments. 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 (initially from TSP and later from PR) and at comparatively low cost.

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INTRODUCTION

Bangladesh is a densely populated agricultural country where rice (*Oryza sativa* L.) is the most extensively cultivated cereal crop. It is the staple food crop of Bangladesh. It has 8.65 million hectares of arable land of which 75% is devoted to rice cultivation (BBS, 2004). Rice based cropping systems has been practiced in Bangladesh since the beginning of modern agricultural practices. The climate and soil of Bangladesh are favorable for year round rice cultivation.

In Bangladesh there are three diverse growing seasons of rice namely *aus*, *aman* and *boro*, among these three seasons, transplanting *aman* rice covers the largest area. In Bangladesh about two-thirds of the cultivated land area is occupied by rice (AIS, 2000). Increased rice production in this country is essential to meet the food demand of the teeming population. Unfortunately, the yield of rice is very low in Bangladesh (3.34 t ha^{-1}) compared to Australia (9.65 t ha^{-1}), Korean Republic (6.59 t ha^{-1}), Japan (6.70 t ha^{-1}) and Spain (6.59 t ha^{-1}) respectively (FAO, 2002). Nutritional deficiency in soil is one of the major constraints which may lead to yield decrease by many folds.

Phosphorus is the second most important nutrient element (next to nitrogen) that has been found limiting for crop production in Bangladesh. Deficiency of phosphorus is widespread in Bangladesh soils. Soil fertility status of Bangladesh soils has declined considerably with the beginning of green revolution in mid-sixties with intensification of crop production.

Phosphorous is needed in adequate quantity in available source for the growth, reproduction, yield and quantity of any crop. It is indispensable for all forms of life because of its genetic role in RNA 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).

In Bangladesh phosphorus is chiefly applied in the form of Triple Super Phosphate (TSP) and Single Super Phosphate (SSP). Very recently Di-ammonium Phosphate (DAP) and Mono-ammonium Phosphate (MAP) has been introduced in Bangladesh. These water soluble phosphates have been commonly used as the phosphatic fertilizer by the farmers in Bangladesh. But the main problem concerning phosphatic fertilizer is its fixation with soil complex within a very short period of application rendering more than two-thirds unavailable (Mandal and Khan, 1972). It may also be mentioned here that TSP is being produced in Bangladesh, in a limited scale using imported Rock Phosphate (PR) with a production capacity of 1,52,000 metric ton annually. It can meet only 25% of the total phosphorus fertilizer requirement of the country. Requirement of bulk of phosphorus fertilizer of the country is met through import form abroad, that requires lots of foreign currency of the country each year.

Rock phosphate (PR) is the cheapest and economic source per unit of phosphorus (Hoffland, 1991) which is not directly being used in the crop field of this country. But powdered Rock Phosphate (PR) can be applied directly in the field. Direct application of Rock Phosphate (PR) as a source of phosphorus has been found effective in acidic and P fixing soil especially for long duration crops (Mitra *et al*. 1992). Soils and climatic conditions are also favourable for direct application of PR. It is considered as a promising source of P for crop use in acidic soil, specially red ones.

Rock phosphate is a source not only of phosphorus, but it also contains variable amounts of other essential nutrients like calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), copper (Cu) and Zinc (Zn) (Dev, 1990). The presence of Ca gives it a neutralizing value (CaO equivalent). Therefore, in the long term, the use of PR with a good neutralizing value on acid soils offers the maximum possible scope for the fertilization of PR.

A considerable area of land of our country is acidic in character, which is not suitable for using water soluble phosphatic fertilizers. Since, rock phosphate is quite cheap and has long term effects on availability of phosphorus, the direct application of finely ground rock phosphate may be an attractive and alternative to the use of the more expensive soluble phosphorus fertilizers for certain crops and soils specially acid one (Hammond *et al.* 1986). However, PR is usually the least costly source of phosphorus and an economically efficient way to supply phosphorus to crops provided sufficient PR is incorporated in the soil to release sufficient phosphorus for a productive and sustainable cropping system. Thus, the use of PR for the amelioration of acid tropical soils should be considered as a capital investment. On some cases, this investment may be very large but, without it, perhaps other investments should not be made in the tropical uplands (Barrow, 1990).

Considerable research has been conducted in recent years on the PRs compared to other water soluble phosphorus sources (e.g. SSP, TSP, DAP etc.) using rice, maize, wheat etc. as test crops (Hammond *et al*., 1986 and Marwaha *et al*., 1981)in various places of the world. But in Bangladesh, a little research work has been done in this aspect. Since, rock phosphate is quite cheap and has long term effect on availability of P, its uses will be very good as a P fertilizer and also expected to bring socio-economic benefits to the farmers. From this view point, the experiment was conducted at Sher-e-Bangla Agricultural

University farm under the agro-ecological zone of Modhupur Tract (AEZ-28) with the following objectives:

i. To determine the effect of PR on yield of upland high yielding variety of rice (BRRI Dhan 39) compared with TSP.
ii. To compare the relative efficiency of PR with TSP as a source of P for rice
iii. To determine the effect of different sources of phosphorus on N, P and K status of soil
iv. To determine the effect of different sources of phosphorus on N, P& K uptake by rice.
v. To study the socio-economic benefits of PR as a source of phosphorus.

REVIEW OF LITERATURE

Rock Phosphate is the raw materials for manufacture of TSP and SSP fertilizers. It is more or less unknown as a fertilizer phosphorus to the farmers for use in producing crops in Bangladesh. Although an extensive research has been carried out in the world on rock phosphate as a phosphorus fertilizer, yet the work on comparative performances of rock phosphate with commonly used fertilizers such as TSP, SSP, DAP etc. is very limited particularly under Bangladesh situations. An attempt is made to review the available literature pertaining to the present study in this chapter.

2.1 Influence of rock phosphate on yield of crops

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

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 P_2O_5 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.

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 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 pattern 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.

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.

Villarroel 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_2O_5 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.

Datta and Gupta (1985) in two field trials with paddy, with P supplied as rock phosphate, single superphosphate, and bonemeal, singly and in various combination, reported that rock phosphate produced the highest paddy yields.

Muller *et al.* (1986) undertook a long term experiment to investigate the effects of various types of phosphorus fertilizer conversion in the 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 Gangwar (1986) stated that rice grown on a clay acid soil (pH 5.7) with an application of 100 kg P_2O_5 ha^{-1} as rock phosphate, single superphosphate or their mixture gave 3 years average paddy yield of 3.65, 3.28 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 yields.

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.

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^{-1} as PR. The superiority of PR was due to its effect in releasing P bound in the acid sulphate soil.

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^{-2} and evaluated that the highest yield of 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 P_2O_5 ha^{-1} as SSP + PR, followed by 30 + 30 kg P_2O_5 ha^{-1} also as SSP + PR whereas yields and gross returns were lower with P as SSP or PR only.

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.

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_2O_5 ha^{-1}, not only increased yields of corn, 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 P_2O_5 ha^{-1} as superphosphate, 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}.

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 (1:1ratio) 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 Hellums *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 underground 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.

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.

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, 5.48-5.73 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 505, 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 the 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.

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. Variations in crop yield due to PR or superphosphate application were not significant.

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_2O_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.

Kumar *et al.* (2002) conducted a two years field experiments to evaluate P sources from 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^{-1}) were tested in kharif rice and succeeding black gram (rabi) cultivated with and without P application. 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. From the results obtained, mussoorie rock phosphate can be effectively utilized as a source of P to rice-black gram crop sequence as it recorded on par rice equivalent yields and gross returns when compared to SSP.

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. Application of PR (210 kg P ha^{-1}) increased rice yield and also gave the highest net benefit.

Rahman (2005) conducted two experiments in two different regions, one at BINA 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.

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

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_2O_5 ha^{-1} on the grain and straw yields and chemical composition of grain and straw of rice.

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.

Rodrigueze *et al*. (2002) evaluated that partial acidulation (PA) of some rock phosphate (PR) was found to be highly effective compared to their natural PR when evaluated through 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 the 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% for cowpea.

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.

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

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.

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.

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 was 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.

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.

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.

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 N, P, K and S content as well as uptake by rice plant were increased due to application of PR (210 kg P ha^{-1}) also highest net benefit was found.

Rahman (2005) conducted two experiments in two different regions, one at BINA 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. in crop yield due to PR or superphosphate application were not significant.

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^{2+} and the acidic environment required for the release of P from PR.

2.4.2 P availability

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^{2+} etc. An indigenous PR was beneficial as a source of P in acid soil.

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

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.

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

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

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.

Rock phosphate as an alternative source of P was evaluated in a P deficient calcarious vertisol. Application of rock phosphate gave paddy and straw yield of rice comparable to those with SSP. Rock phosphate treatment gave a better residual response than SSP (Rabindra *et al.*, 1986).

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.

Parotohardjono and Adiningsih (1991) conducted a field experiment on the direct application of PR for various upland crops including corn, 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_2O_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 with 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.

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.

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.

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.

2.6 Net profit due to application of rock phosphate

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.

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 (1989) 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.

Several phosphate rocks (PRs) and soluble triple superphosphate (TSP) were evaluated by Hellums *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.

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}.

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.

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_2O_5 ha^{-1} on rice cv. Panama-1048. Data were presented which increased profits compared with lime and TSP application.

2.7 Economic efficiency or Agronomic effectiveness

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.

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.

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.

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 warm moist climate.

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 partially 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

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.

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%.

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.

Ng *et al.* (1993) mentioned that the effect of one time application of 300 kg P_2O_5 as TSP was compared with the same amount of P_2O_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.

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.

MATERIALS AND METHODS

The experiment was conducted in the Shere-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28 during the T. *aman* season of 2004. For better understanding the site are shown in the Map of AEZ of Bangladesh (Fig. 1).

This chapter presents a brief description of the soil, crop, experimental design, treatments, cultural operations, collection of soil and plant samples and analytical methods followed in the experiment. This chapter has been divided into a number of sub-heads described as below:

3.1 Experimental Details of the Site

3.1.1 Soil

The experiment was carried out in a typical rice growing soil of the Shere-e-Bangla Agricultural University (SAU) farm, Dhaka, during T. *aman* season of 2004. The farm belongs to the General soil type, Shallow 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.

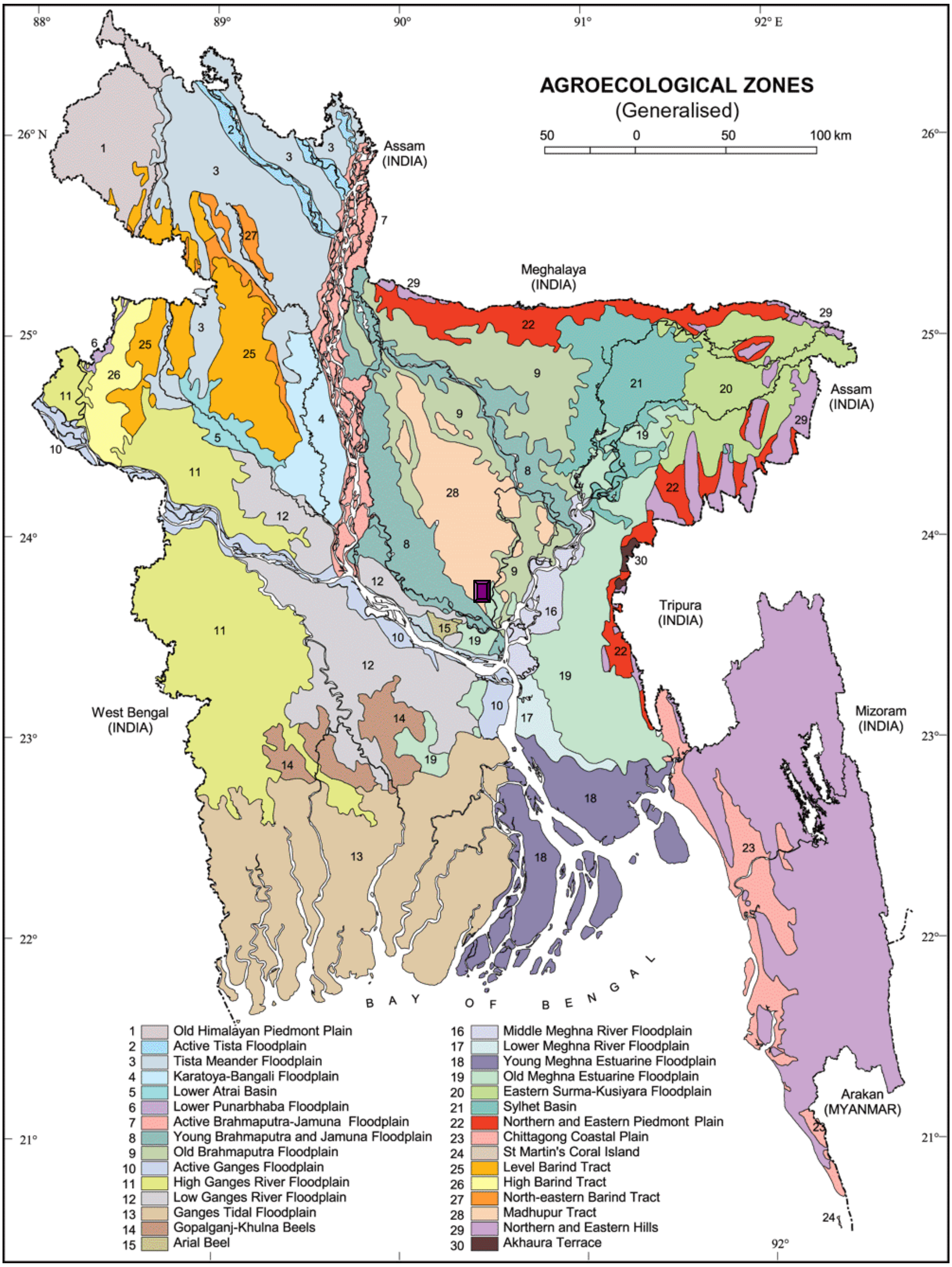

Fig. 1. Map showing the experimental sites under study

3.1.2 Climate

The climate of the experimental area is characterized by sub tropical accompanied by moderate high rainfall associated with relatively high temperature during T. *aman* season. The average temperature and rainfall data during the cropping period are shown in Appendix I.

Table 1 Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Field Laboratory, SAU, Dhaka
AEZ	Madhupur Tract
General Soil Type	Shallow 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 Physical and chemical properties of the initial soil

Characteristics	Value
Partical 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

3.1.3 Crop

BRRI Dhan 39, a high yielding variety of rice, was used as a test crop. The variety was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, as a short duration T. *aman* rice.

3.1.4 Land preparation

The experimental field was first opened on 24 June, 2004 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: 8m × 5m

Block to block distance: 1m

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 five 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 × 4). The unit plot size was 8m × 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.

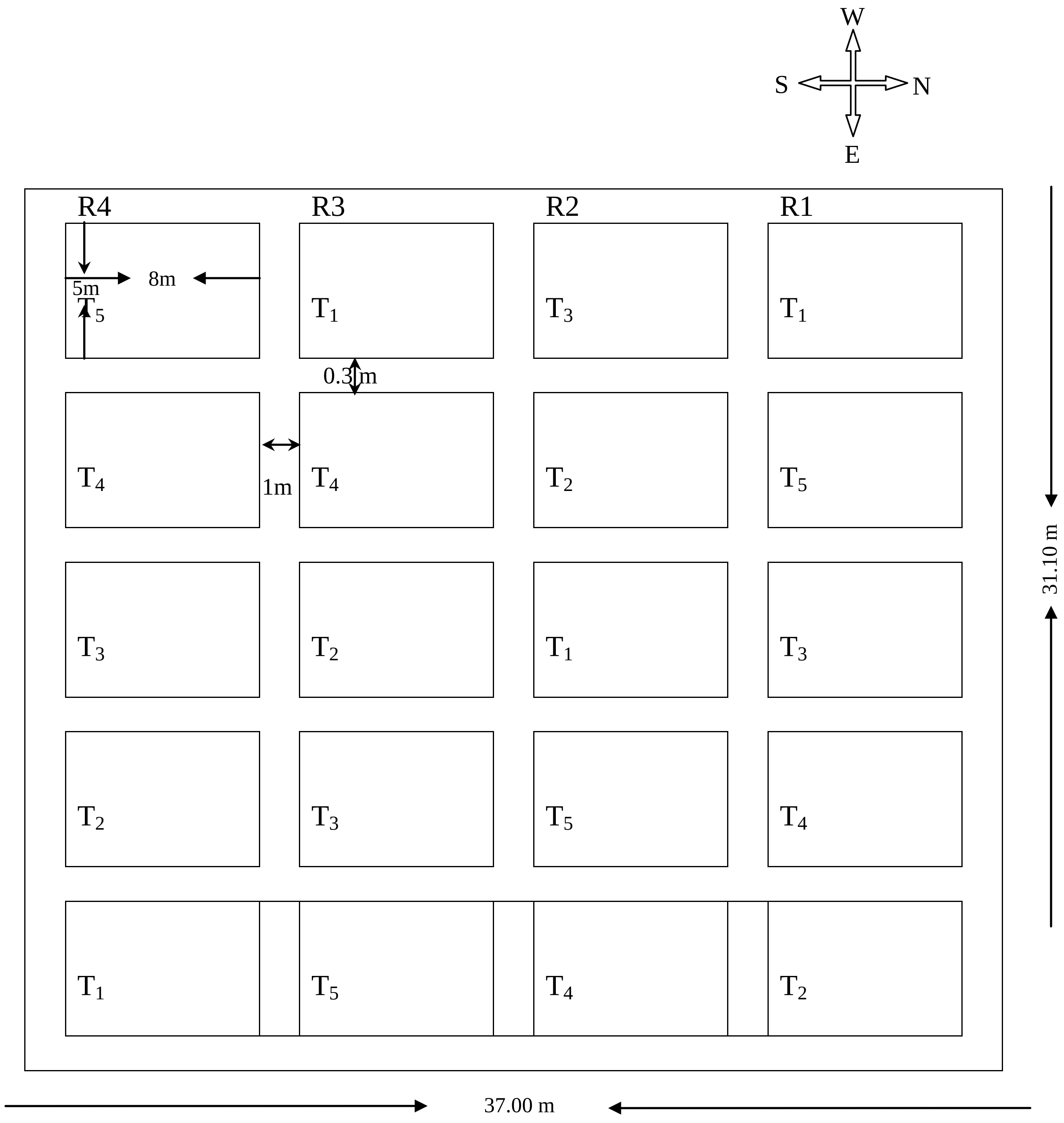

Fig. 2 Layout of the experiment

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 and covered with a thin layer of fine earth. 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 sample was 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 rates of rock phosphate, one rate of mixed rock phosphate & TSP and a control. Treatments were as follows:

T_1 = Control (0 kg P ha^{-1}).

T_2 = 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}

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

Source of PR: Morocco PR are used for the experiment. The rates and sources of nutrients used in this experiment are given in Table 3.

Table 3 Sources and rates of different elements in the experiment

Nutrient element	Rate/ha	Source
Nitrogen (N)	75 kg	Urea
Phosphorus (P)	35 kg P	TSP
	35 kg P	PR
	210 kg P	PR
Potassium (K)	50 kg K	MOP
Sulphur (S)	20 kg S	Gypsum
Zinc (Zn)	3 kg Zn	ZnO

3.1.10 Application of fertilizers

All the fertilizers, except N 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 available P_2O_5 from different sources that were used in the treatments are shown in appendix II.

3.1.11 transplanting of seedling

The seedlings of 35 days old were transplanted in the experimental plots on 19 July 2004. Plant spacing was 25 cm x 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.

3.1.12 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 followed as and when necessary. There were some incidence of insects specially rice hispa, rice stem borer, rice bug, which was controlled by spraying Diazinon pillersuphan, Darsban and Malatheon. Irrigation was also done to the plots from the nearest pond water as per needed and water level was maintained at 5 cm on soil surface in each plot in growing period of the crop.

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

At maximum tillering stage on 20th August and panicle initiation stage on 19 September, 10 hills were harvested randomly by cutting at the ground level. The harvested hills were first air dried and finally dry matter yield was recorded on oven-dry basis and stored for nutrient analysis.

3.1.14 Harvesting

The crop was harvested at maturity on 25 October 2004. The harvested crop was threshed plot-wise. Grain and straw yields were recorded plot-wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw was recorded.

3.1.15 sampling at harvest

Ten 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 grains 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^{-1} on sun-dry basis.

3.1.16 Data collection

The data of the yield contributing characters of the crop were calculated 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)

3.1.16.1 Plant height (cm)

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

3.1.16.2 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 calculated.

3.1.16.3 Panicle length

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

3.1.16.4 Unfilled and filled grains per panicle

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

3.1.16.5 1000 grain weight

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

3.1.16.6 Grain and straw yields

Grain and straw yields were recorded plot-wise and expressed as t ha^{-1} on 14% moisture basis.

3.1.17 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of the Department 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 for % sand, % silt and % clay to the "Marshall's 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 matter with an excess of N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

Total nitrogen of soil was estimated by microkjeldahl method where soil was digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: 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 tapped in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_3$ 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 1N 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.

3.1.18 Chemical analysis of plant samples

3.1.18.1 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 65^0C for 48 hours. The dried samples were then ground with a grinding mill. The prepared samples were put into small paper bags and kept into a dessicator till being used.

3.1.18.2 Digestion of plant samples with sulphuric acid

For N determination an amount of 0.1g plant sample (grain/straw) was taken into a 100 ml kjeldahl flask. An amount of 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$:Se = 100:10:1), 2ml 30% H_2O_2 and 3ml conc. H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes, followed by heating at 200^0C. 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.

3.1.18.3 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, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature raising slowly to 200^0C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6ml of 6N HCl 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.

3.1.18.4 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.

3.1.19 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).

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to application of different rate of rock phosphate (PR) and TSP on growth yield and nutrient uptake by T. *aman* rice (cv. BRRI Dhan 39). The result of studies such as dry matter yield, nutrient content and uptake by rice plant at maximum tillering (MT) and panicle initiation (PI) stages as well as yield attributes, grain and straw yields and chemical characteristics of the soil at post harvest are discussed in this chapter.

4.1 Dry matter yield

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

4.2 Dry matter yield at maximum tillering (MT) stage

Dry matter yield of rice plants at maximum tillering stage ranging from 1.40 to 1.67 t ha^{-1} (Table 4 and Fig. 3) did not differ significantly. Maximum dry matter yield (1.67 t ha^{-1}) was recorded in T_5 treatment with an increase of 19.28%, 11.33%, 10.66% and 1.83% over T_1 (control), T_2 and T_3 and T_4 treatments respectively. Minimum dry matter yield was recorded in control treatment (1.40 t ha^{-1}).

4.3 Dry matter yield at panicle initiation (PI) stage

Application of Rock Phosphate (T_2&T_4), TSP (T_3) and their combination (T_5) increased the dry matter yield significantly at panicle initiation stage. Maximum dry matter production (5.45 t ha^{-1}) was obtained in T_5 treatment, with an increase of 8.36% over control, 5.60% over T_2, 5.60% over T_3 and 0.73% over T_4 treatment (Table 4 and Fig 4). There was no apparent dry matter

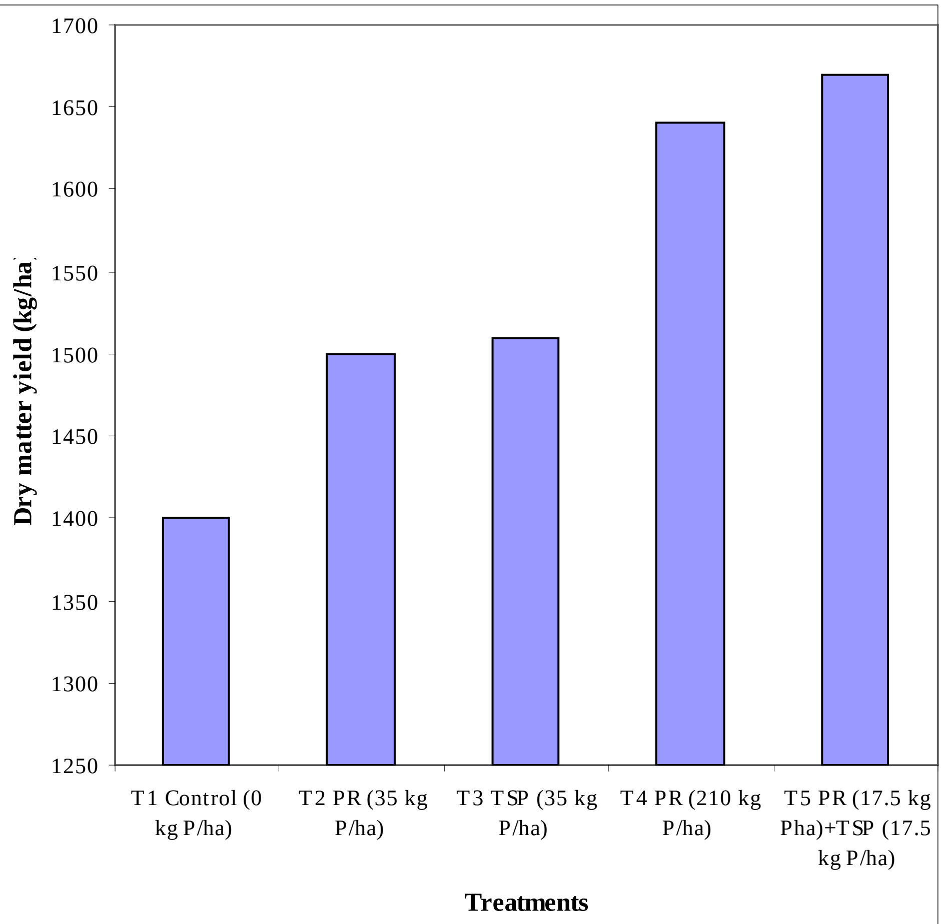

Fig. 3 Effects of different treatments on dry matter yield at maximum tillering (MT) stage.

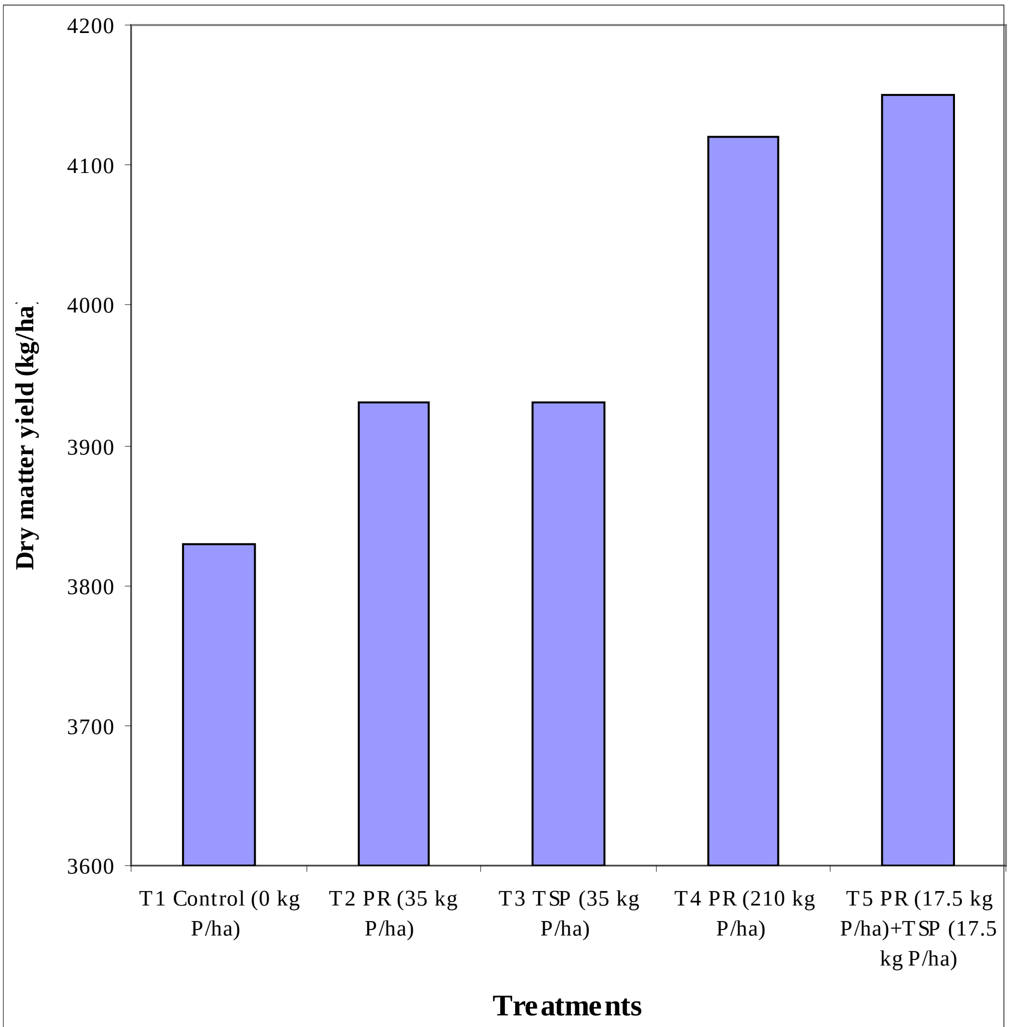

Fig. 4 Effects of different treatments on dry matter yield at panicle initiation (PI) stage.

yield difference between TSP and PR treatment having the same rate of P applied (35 kg P ha^{-1}) at PI stage of the crop. The minimum dry matter production (3.93 t ha^{-1}) was observed in control. In producing dry matter yield at PI stage, the treatments may be remarked in order of $T_5 > T_4 > T_3 > T_2 > T_1$.Rahman (2005) reported that total dry matter production at IP stage was increased significantly due to application of different rates of PR.

4.4 Yield contributing characters

4.4.1 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 (99.68 cm) was attained in the treatment T_5 and the minimum plant height of rice plants (97.20 cm) was obtained in T_1 treatment (Table 5).

4.4.2 Total tillers $hill^{-1}$

The effect of different treatments on total tillers $hill^{-1}$ was statistically significant. The maximum number of tiller $hill^{-1}$ (13.60) was obtained in T_5 (PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}) treatment which was significantly greater than that obtained in T_1, T_2, T_3, and T_4 treatments. However the total tillers per hill did not differ significantly in T_1, T_2, T_3& T_4 treatments. In producing total number of tillers $hill^{-1}$, the treatments may be arranged as $T_5 > T_4 > T_3 > T_2 > T_1$.

4.4.3 Effective tillers $hill^{-1}$

Combined application of PR&TSP (T_5) increased effective tillers per hill significantly over other treatments (Table 5). The maximum number of effective tillers $hill^{-1}$ (12.65) were obtained in T_5 (PR 17.5 kg P ha^{-1} + TSP 17.5 kg P ha^{-1}) treatment.

The lowest number of effective tillers hill^{-1} (10.15) were obtained in T_1 (control P_0) treatment. The effects of judicious application of PR and TSP increased effective tillers hill^{-1}. Rahman (2005) stated that higher rate of application of rock phosphate significantly increased the effective tillers hill^{-1}.

4.4.4 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 (21.92 cm) was attained in T_5 treatment and minimum panicle length (20.81 cm) was attained in control treatment.

4.4.5 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 (27.43) obtained in T_1 (control P_0) treatment which was statistically identical to T_2 (PR 35 kg P ha^{-1}) and T_3 (TSP 35 kg P ha^{-1}) and lowest unfilled grains (23.07) was obtained T_5 (PR 17.5 kg P ha^{-1} $_+$ TSP 17.5 kg P ha^{-1}) treatment which was significantly lower than T1, T_2 and T_3 treatments. It was observed that the judicious application of PR and TSP decreased unfilled grains panicle^{-1}. However, the percentage of unfilled grains panicle^{-1} ranged from 28.53 to 30.60. Lowest percent of unfilled grains was recorded in the T_5 treatment which was superior to other treatments.

4.4.6 Filled grains panicle^{-1}

The filled grains panicle^{-1} varied significantly among the treatments (Table 5). The highest number of filled grains panicle^{-1} (72.00) 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 rest of the treatments. The second highest filled grains panicle^{-1} (68.20) was produced by the T_4 (PR 210 kg P ha^{-1}) treatment which was superior to T_3, T_2 and T_1 treatments. T_3 was superior to T_2 while T_2 was superior to T_1 (control P_0). The lowest filled grains panicle^{-1} (57.90) was obtained in treatment T_1 (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 $T_5>T_4>T_3>T_2>T_1$. 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}.

4.4.7 1000-grain weight

The results (Table 5) indicated that the effects of different treatments on 1000-grains weight were statistically insignificant but 1000-grain weight was increased due to mixed application of PR and TSP. The 1000-grain weight was a stable variable character and grain cannot grow larger than the size of the hull (Yoshida, 1981). The highest 1000-grain weight of 22.63 was found in T_5 and the lowest 22.13 in treatment T_1. 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}.

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 total dry matter production at IP stage was increased significantly due to application of higher rate of PR.

4.5 Yield

4.5.1 Grain yield

The effects of different treatments on grain yield of T. *aman* rice (cv. BRRI dhan 39) reveals a significant variation due to different treatment (Table 6). The grain yield varied from 2.97 to 4.00 t ha^{-1}. The maximum yield (4.00 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 statistically significant to other treatments. The lowest grain yield was (2.97 t ha^{-1}) obtained in T_1 (control P_0) treatment. The second highest yield (3.55 t ha^{-1}) was obtained in treatment T_4 (PR 210 kg P ha^{-1}) which was inferior to T_5 and superior to T_3 (TSP 35 kg P ha^{-1}), and T_1 treatment. In producing grain yield, the treatment may be ranked in order of $T_5 > T_4 > T_3 > T_2 > T_1$. The percent increase in grain yield over control ranged from 34.68%, 19.53%, 7.74% and 17.51%, 7.74% and 17.5% in treatment T_5, T_4, T_3 and T_2 respectively (Shown in Fig. 5). The result might be due to judicious application of PR and TSP on rice field resulted in more effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which contributed to increased grain yield. 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 as 1:1 ratio was more effective than PR only in increasing yield (Rajkhowa *et al* 1998). (Policegoudar *et al* 1994) stated that rock phosphate and acidulate rock phosphate increased rice yield compared to SSP. Similar results were also found many researcher.

4.5.2 Straw yield

The effect of different treatments on the straw yield of rice was markedly influenced which is given in Table 6. The highest straw yield (6.64 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 significant to other treatments. The second highest straw yield (5.91 t ha^{-1}) was obtained in treatment T_4, which is statistically similar to the treatment T_3. The percent increase in straw yield in different treatment ranged from 2.08% to 25.52% over control (Table 6 and Fig. 5). The highest percent increase was obtained in treatment T_5 and the lowest increase in the treatment T_2. 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 observations were also found many researcher.

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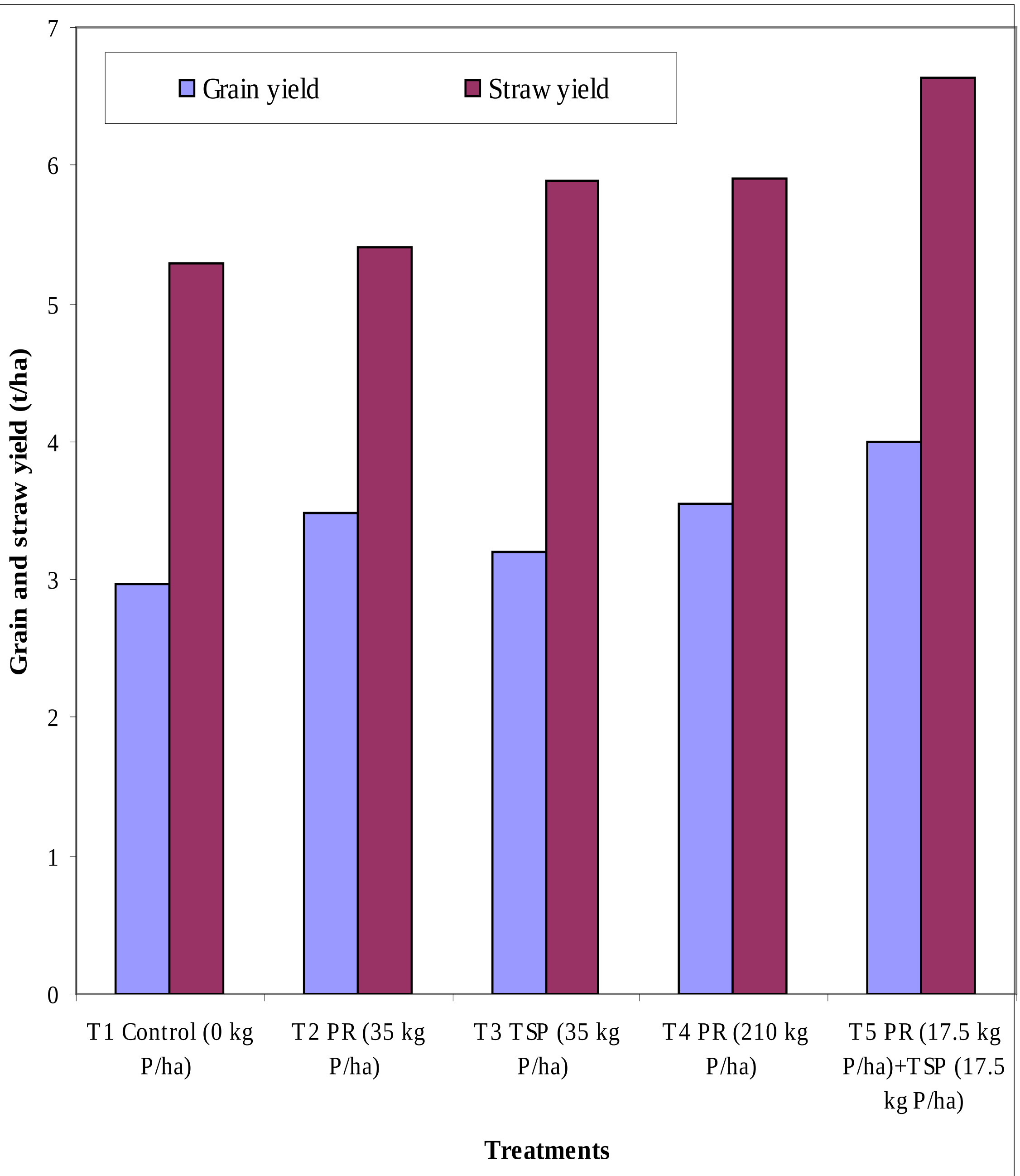

Fig. 5 Effects of different treatments on grain and straw yield of T. aman rice.

4.5.3 Relationship between grain yield and straw yield

Fig. 6 showed that there was a positive correlation ($R^2 = 0.6678$) between grain yield and straw yield. The relationship is described by yield response function $y = 1.1214(x) + 1.9661$ where y indicates straw yield, which varied with the grain yield levels x.

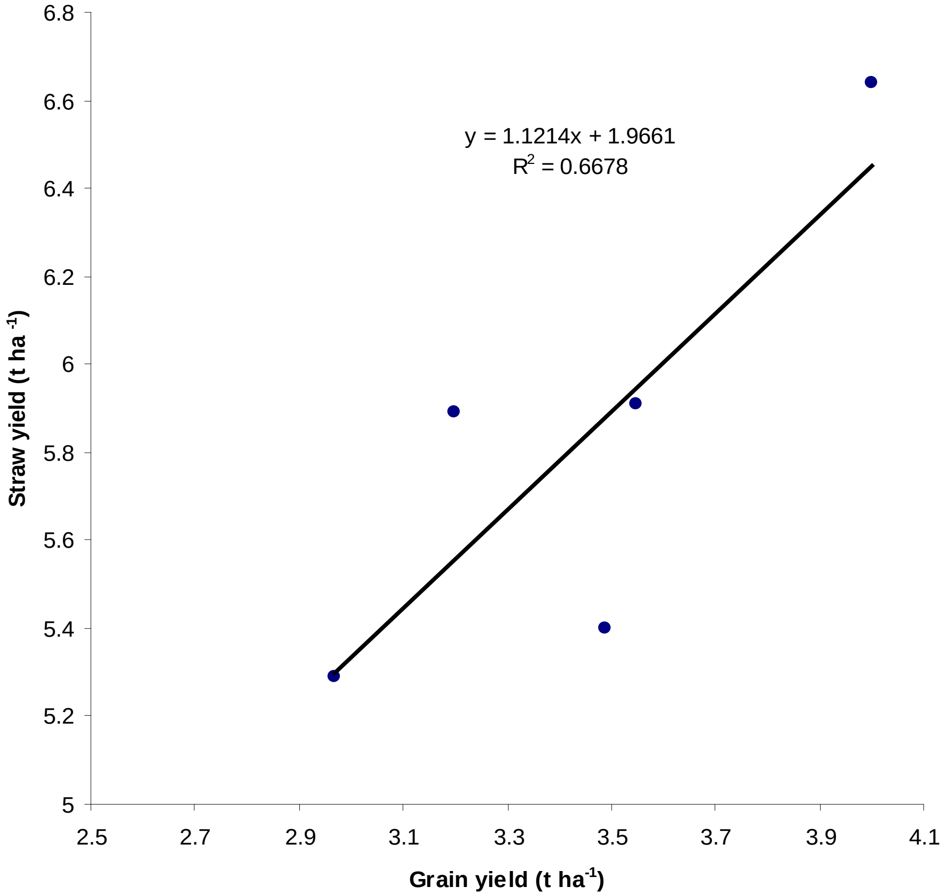

Fig. 6 Relationship between grain and straw yield of rice

4.6 Nutrient content and uptake at maximum tillering (MT) stage

4.6.1 N content and uptake by rice plant

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 1.82% to 2.38% at this stage. The minimum N content was obtained in the control, which was statistically identical to T_2, T_3 and T_4 treatments. The treatment T_5 was recorded the highest N content, which was also statistically identical to T_4 treatment.

The N uptake by rice plant was found statistically significant due to different treatments. The highest N uptake (39.75 kg ha^{-1}) was obtained in T_5 treatment and the lowest N uptake (25.48 kg ha^{-1}) was observed in control. The N uptake by T_2 and T_3 treatments were statistically identical. The N content and uptake by rice plant increased due to application of PR (Islam, 2005).

4.6.2 P content and uptake by rice plant

Application of PR and TSP markedly increased the concentration of P in rice plant in different treatments. The P content in rice plant ranged from 0.25% to 0.36% (Table 7). The maximum value was noted in the treatment T_5 and the lowest P content was recorded in control treatment. The P content due to different treatments ranked in the order of $T_5>T_4>T_3>T_2>T_1$. T_5 treatment had shown better effect over other treatments, judicious application of PR and TSP increased the P content in rice plant. P content increased at MT stage due to higher rate of application of PR (Rahman, 2005).

P uptake by BRRI Dhan 39 also varied significantly (Table 7). The treatment T_5 obtained maximum P uptake (6.0 kg ha^{-1}) where as the control treatment obtained minimum P uptake (3.5 kg ha^{-1}). P uptake by T_2 and T_3 were statistically identical. P uptake also increased at MT stage due to higher rate of application of PR (Rahman, 2005).

4.6.3 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 (3.20%) was observed both in T_5 and T_4 treatment, which was identical to T_3 and T_2 treatments and minimum value (2.69%) was obtained in control and the K content due to different treatments ranked in the order of $T_5>T_4>T_3>T_2>T_1$.

K uptake also showed significant response due to different treatments. The highest K uptake (53.46 kg ha^{-1}) was recorded in T_5 treatment and the lowest K uptake (37.66 kg ha^{-1}) was found in the control and K uptake due to different treatments ranked in the order of $T_5>T_4>T_3>T_2>T_1$. The K content as well as uptake by rice plant increased due to application of PR (Islam, 2005).

4.6.4 S content and uptake by rice plant

A significant increase in S content by rice plant was recorded due to different treatments (Table 7). The highest value (0.4%) was obtained in T_5 treatment which was statistically significant with other treatments. The minimum value (0.31%) was obtained in T_3.

S uptake by rice plant also significantly increased due to different treatments. The highest S uptake was found in T_5 treatment (6.68 kg ha^{-1}) and the lowest S uptake (4.97 kg ha^{-1}) was obtained in control treatment.

The treatments T_1, T_2 and T_3 were statistically identical to S uptake. The S content as well as uptake by rice plant increased due to application of PR (Islam, 2005).

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

4.7.1 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 (2.28%) was obtained in T_5 treatment and control treatment showed the minimum N content (1.71%) in control treatment which was statistically identical to T_2, T_3 and T_4 treatments.

N uptake by BRRI Dhan 39 also varied significantly. The highest N uptake (94.62 kg ha^{-1}) was obtained in T_5 treatment and the minimum value (65.49 kg ha^{-1}) was noted in control treatment. The treatment T_2 and T_3 were statistically identical.

4.7.2 P content and uptake by rice plant

The P content in rice plant at PI stage was significantly influenced by different treatments (Table 8). The P content ranged from 0.235 to 0.30% and the minimum content was obtained in the control. The highest P content was obtained in T_5 treatment.

A significant increase in P uptake by rice plant was also recorded due to different treatments (Table 8). The treatment T_5 showed the maximum P uptake (12.45 kg ha^{-1}) and control treatment showed the lowest P uptake (9.00 kg ha^{-1}). P applied in the form of TSP was found similar effect over PR having same rate of P application (35 kg P ha^{-1}). P content and uptake were increased at PI stage due to higher rate of application of PR (Rahman, 2005).

4.7.3 K content and uptake by rice plant

The K content in BRRI Dhan 39 at panicle initiation stage was significantly influenced by different treatments and ranged from 2.13% to 2.86% (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 81.58 to 118.69 kg ha^{-1}. The highest K uptake (118.69 kg ha^{-1}) was noted in T_5 treatment and the lowest value (81.58 kg ha^{-1}) was found in control. The treatment T_2, T_4 and T_5 were statistically identical. The K content and uptake by rice plant increased due to application of PR (Islam, 2005).

4.7.4 S content and uptake by rice plant

Result presented in Table 8 showed that S content did not increase significantly by different treatments. S content in rice plant ranged from 0.28% to 0.345%. 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 (4.31 kg ha^{-1}) was obtained in T_5 treatment and the lowest value (10.72 kg ha^{-1}) was found in control and the S uptake ranged from 10.72 to 14.31 kg ha^{-1} (Table 8). The treatments T_4 and T_5 were statically identical. S content and uptake were increased at PI stage due to higher rate of application of PR (Rahman, 2005).

4.8 Nutrient content and uptake in grain and straw

4.8.1 N content in grain and straw

Application of PR and TSP did not show any significant effect on the N content in grain. The concentration of N in grain ranged from 1.75% to 1.82% (Table 9 and Fig. 7). The maximum N content was recorded both in T_5 and T_3 treatment and the lowest N content was observed in control treatment. But all the treatment did not differ significantly over control.

On the other hand N content in straw was found statistically significant and ranged from 1.26% to 1.47% and the maximum concentration of N was noted in T_5 treatment, which was statistically similar to T_4 treatment. The lowest N content was obtained in the control. N content in grain and straw were maximum by the application of PR (Islam, 2005).

4.8.2 N uptake in grain and straw

N uptake by grain and straw was influenced significantly due to application of PR and TSP. N uptake by grain ranged from 51.97 to 72.80 kg ha^{-1}. The maximum N uptake (72.80 kg ha^{-1}) was recorded in T_5 treatment and the lowest N uptake (51.97 kg ha^{-1}) was observed in control (Table 9 and Fig. 7). T_2, T_3 and T_4 treatment showed statistically similar results which were significantly inferior to T_5 treatment.

In case of straw, the highest N uptake (97.60 kg ha^{-1}) was noted in T_5 treatment, which was superior to any other treatments and the lowest N Uptake (66.65 kg ha^{-1}) which was inferior to other treatments.

The total N uptake ranged from 118.62 to 170.4 kg ha^{-1}. The maximum total N uptake was found in T_5 treatment and the minimum total N uptake was recorded in control.

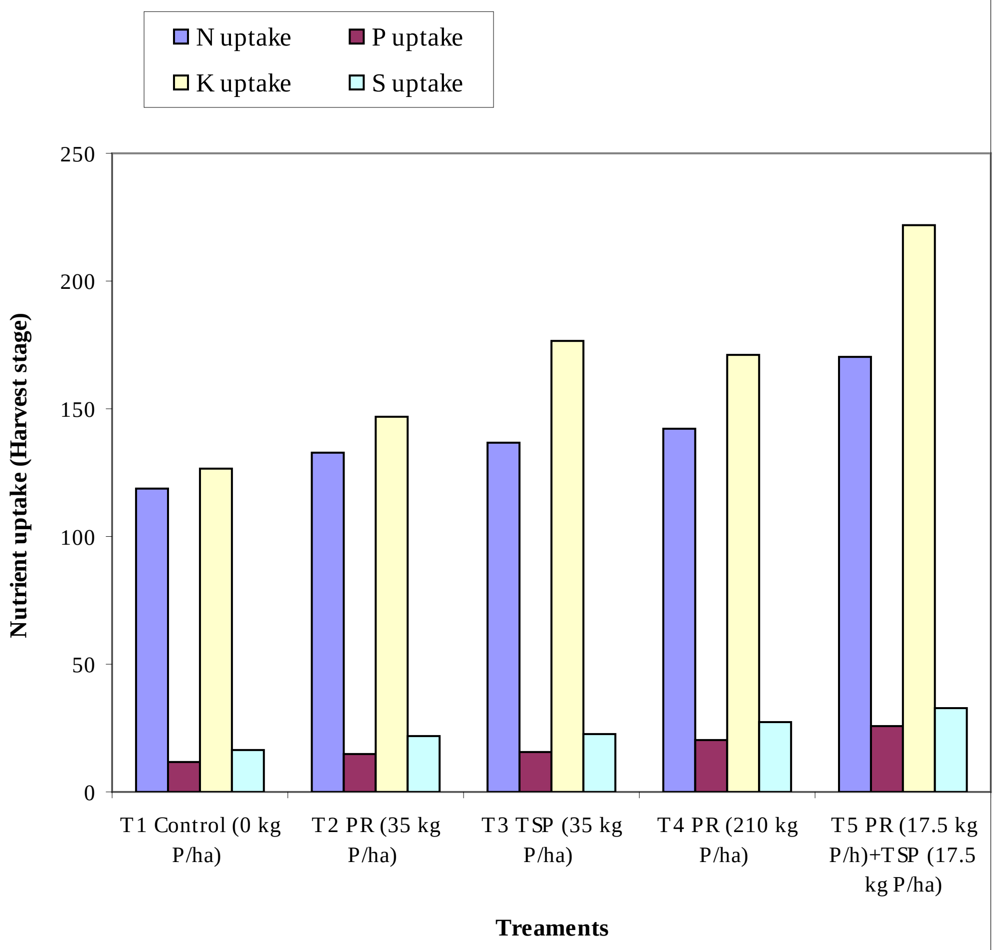

Fig. 7 Effects of different treatments on N, P, K and S uptake by T. aman rice at harvest stage.

The second highest N uptake was observed in T_4 treatment, which was statistically identical to T_2 and T_3 treatments.

It may be explained that P fertilization increased the N content and uptake in cereals irrespective of different sources. N uptake 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* (1999).

4.8.3. P content in grain and straw

The P content in grain and straw was significantly affected by the different treatments. The content of phosphorus in grain ranged from 0.215% to 0.365% (Table 10). The maximum P content (0.365%) was attained in T_5 treatment followed by T_4 (0.315%), T_3 **(**0.27%**)** and T_2 (0.24%). 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 (0.17%) followed by T_4 (0.151%), T_3 (0.125%) and also T_2 (0.125%) and the minimum content was observed in control treatment. However, in both cases (grain and straw), TSP had shown similar effect over PR having the same rate of P (35 kg ha^{-1}).

4.8.4 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 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 (11.28 kg ha^{-1}) in T_5 treatment and minimum was (5.55 kg ha^{-1}) in control. The total uptake range varied from 11.94 to 25.88 kg ha^{-1}. P uptake 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* (1999). Islam (2005) also reported that P uptake in grain and straw were maximum by the application of PR.

4.8.5 K content in grain and straw

The K content in grain was found statistically significant and ranged from 0.63% to 0.76% (Table 11). The maximum K content (0.76%) was recorded in T_5 treatment and the control treatment produced minimum K uptake (0.63%). The next highest K content was recorded in T_4 treatment and the treatments may be arranged as T_5>T_4>T_3> T_2> T_1. K content in grain and straw were maximum by the application of PR (Islam, 2005).

In case of straw, K content varied due to different treatments. All the treatments increase the K content significantly over control. The maximum K content by straw was observed in T_5 treatment which was statistically identically to T_4 and T_3 treatments, and the minimum K content was obtained in control treatment and the range was 2.04% to 2.73%.

4.8.6 K uptake in grain and straw

K uptake by grain ranged from 18.71 to 30.40 kg ha^{-1} (Table 11). The maximum K uptake was recorded in T_5 treatment and the lowest K uptake was observed in control treatment. The next highest K uptake was observed in T_4 treatment.

In case of straw, K uptake varied due to direct application of PR. The uptake in straw ranged from 107.91 to 181.27 kg ha^{-1} (Table 11). The highest K uptake was observed in T_5 treatment and the lowest K uptake was recorded in control treatment.

Results in Table 4.1.8 showed that total K uptake varied significantly (from 126.62 to 221.67 kg ha^{-1}) due to different treatments. The maximum K uptake (221.67 kg ha^{-1}) was recorded in T_5 treatment and the lowest K uptake (126.62 kg ha^{-1}) was observed in control.

Conclusion may be drawn that phosphorus fertilizer can significantly boost up the K content in grain and straw. P uptake 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* (1999).

4.8.7 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 0.129% to 0.165% (Table 12). The highest S content was noted in T_5 treatment which was statistically identical to T_4 and T_2 treatment. The lowest S content was noted in control.

In case of straw, S content varied from 0.245% to 0.395% (Table 12). The maximum S content was observed in T_5 treatment and the minimum S content was observed in control. S content increased by the grain due to higher rate of application of PR (Rahman, 2005).

4.8.8 S uptake in grain and straw

Results shown in Table 12 indicated that S uptake by grain was also significantly influenced by the different treatments.

The range of S uptake observed in grain was 3.82 to 6.60 kg ha^{-1}. The maximum S uptake (6.60 kg ha^{-1}) was recorded in T_5 treatment and the lowest value (3.82 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 12.96 to 26.23 kg ha^{-1}.

Application of PR and TSP had significant effect on total S uptake (Table 12). The highest total S uptake (32.83 kg ha^{-1}) and the lowest total S uptake (16.78 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.

4.9 Characteristics of the post harvest soils

Table 13 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 6.00 to 6.50. The highest pH value (6.50) was recorded in T_2 treatment and lowest pH value (6.00) was recorded in control treatment. The variations of pH value among the treatments were insignificant.

The organic matter content of the post harvest soil ranged from 0.76% to 0.78% (Table 13). The maximum organic matter content (0.78%) was obtained in control treatment and the minimum organic matter content (0.76%) was obtained in the treatment T_2.

The total N content of the post harvest soil ranged from 0.0477% to 0.052% (Table 13). The highest total N content was observed in T_2 treatment. The second highest total N content was found in T_1, T_3 and T_5 treatments.

Available S content of post harvest soils influenced significantly due to different treatments (Table 13). The maximum S content (30.00 ppm) was observed in control treatment and the lowest S content (21.00 ppm) was observed in T_5 treatment. The treatments T_3 and T_4 were statistically similar.

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 31.50 to 39.00 ppm. The highest P content was recorded in the treatment T_5 (39.00ppm) followed by T_4 (37.50 ppm), T_3 (33.75 ppm) and T_2 (33.00 ppm). The lowest P content was found in control.

The K content of post harvest soils ranged from 0.1575 to 0.14 meq/100g soil (Table 13). The highest K content was observed in T_5 treatment which was statistically identical to T_3 and T_4 treatments and the lowest K content was recorded in T_2 treatment, which was statistically similar to T_5 treatment. The treatments T_2 and T_3 were statistically similar.

4.10 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 Dhan39) showed that the highest net benefit of Tk. 25165.00 ha^{-1} was obtained in T_5 treatment followed by Tk. 20385.00 ha^{-1}, Tk. 17675.00 ha^{-1}, Tk.17475.00 ha^{-1} and Tk. 13576.00 ha^{-1} in T_2, T_1, T_3 and T_4 treatments respectively (Table 14). Supplementing the rock phosphate with superphosphate in acid soils was more economical (Krishnappa *et al* 1991).

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy Field Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka, during T. aman season in 2004 to study the influence of direct application of rock phosphate (PR) on the growth, yield and nutrient uptake of BRRI Dhan 39 under Modhuput Tract (AEZ 28).

Five treatments were imposed in the experiment. The trail was laid out in Randomized Complete Block Design (RCBD) with four replications. The treatments used were T_1: 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}) and T_5 PR (17.5 kg P ha^{-1}) + TSP (17.5 kg P ha^{-1}).

At the maximum tillering stage and panicle initiation stages, plant samples (10 hills randomly selected) were collected from each plot for estimating growth and analysis of nutrient content and their uptake. The plant characters were recorded on each plot after final harvest. The data included were plant height, total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, panicle length, unfilled and filled grains $panicle^{-1}$, 1000-grain weight and grain and straw yields. Chemical analysis of grain and straw and soil samples was also done. The collected data were analyzed statistically following Duncan’s Multiple Range Test (DMRT).

There were no significant differences in different treatments on dry matter yield of rice plants at the MT & PI stages, which ranged form 1400 kg ha^{-1} (control treatment) to 1670 kg ha^{-1} (T_5 treatment) and 3830 kg ha^{-1} to 4150.00 kg ha^{-1} 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 (12.65 hill^{-1}) and the minimum number of effective tillers (10.15 hill^{-1}) was found in control. The maximum number of filled grains panicle^{-1} (72.00) was recorded in T_5 treatment while the lowest value (57.90) was in control. The weight of 1000 grains varied from 22.13 to 22.63g and had no significant difference.

The maximum grain yield (4.00 t ha^{-1}) was attained in T_5 treatment which showed an increase of 34.68% over control. The second highest grain yield was obtained in T_4 treatment (3.55 t ha^{-1}) followed by T_2 (3.49 t ha^{-1}), T_3 (3.20 t ha^{-1}) and control (2.97 t ha^{-1}). Straw yield of rice plants followed very similar pattern as that of grain. The maximum straw yield (6.64 t ha^{-1}) was obtained in T_5 treatment and the lowest value (5.19 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 (2.38%, 0.36%, 3.20% and 0.40% respectively) were recorded in T_5 treatment and similarly highest N, P, K and S uptake (39.75 kg ha$^{-1,}$ 6.01 kg ha^{-1}, 53.44 kg ha^{-1}, 6.86 kg ha^{-1}, respectively) were recorded in T_5 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 per cent of N, P, K and S varied from 1.75 to 1.82, 0.215 to 0.365, 0.63 to 0.76 and 0.129 to 0.165, respectively and the nutrient uptake of grain analyzed revealed the amount of N, P, K and S varied from 51.97 to 72.80 kg ha^{-1}, 639 to 14.60 kg ha^{-1}, 18.71to 30.40 kg ha^{-1} and 3.82 to6.6 kg ha^{-1}, respectively. The nutrient content as well as uptake by straw followed very similar pattern as that of grain. In all the cases, the highest value was attained in T_5 treatment and the lowest value was attained in control. P applied in the form of combination of PR and TSP was found to have produced better effects over other treatments. This is because, 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 range varied from 6.00 to 6.50. All the treatments recorded higher pH value as compared to the initial soil. The organic matter content of the post harvest soils ranged from 0.78 to 0.775. The highest value was attained in control and the lowest value was observed in T_2 treatment. The N, P, K and S content of the post harvest soils ranged from 0.048 to 0.052%, 31.50 to 39.00 ppm, 0.1575 to 0.1325 meq/100 g soil and 21.00 to 30.00 ppm, respectively. The highest P and S content was recorded in T_4 treatment while the maximum N and K values were obtained in T_2 treatment and control respectively.

The results of economic analysis showed that the highest net benefit of Tk.25165.00 ha^{-1} was obtained in T_5 treatment and the lowest net benefit of Tk.17675.00 ha^{-1} was found in control.

Thus, it may be concluded here that the use of rock phosphate will entirely be a new source of P fertilizer to be used in the country. Present work with T. *aman* rice as the first crop in the trial with rock phosphate. In general indicates, TSP had better performance over PR having the same rate of P (35 Kg P ha^{-1}), but treatment T_5 with combined application of PR and TSP had shown the best results followed by T_4 with the application of high amount of PR (210 kg) at a time . The experiment needs to be repeated in the same site to find out residual effect of PR due to its low solubility. However, its low price and residual effect of cropping system could be an added factor for easy acceptance of PR fertilizer compared to other phosphatic fertilizers. Therefore, it is still premature state to make any comment on effectiveness of PR fertilizer for crop production and its socio-economic impact on farmer's acceptability.

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APPENDICES

Appendix I: Average temperature, humidity and rainfall data during July to December, 2004 (Site-Dhaka)

Month	** Air temperature (^0C)	** Relative Humidity (%)	* Rainfall (mm)
June	28.34	88.23	332.7
July	28.31	87.00	787.2
August	29.22	84.55	253.4
September	27.66	91.30	269.7
October	27.14	75.25	208.00
November	24.04	69.52	00.00
December	21.54	70.61	00.00

* = Monthly total
** = Monthly average
Source: Bangladesh Meteorological Department (Climatic Division), Agargaon, Dhaka-1212.

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

Sources of fertilizer	Available P_2O_5 (%)
Rock Phosphate(PR)	25-40
Triple Super Phosphate(TSP)	44-52

Source: Bangladesh Fertilizer Association (BFA), City Heart 10th Floor, Room# 8, 67, Nayapalton, Dhaka-1000.