



Effect of Reduced Rates of N, P and K on the Yield of Rice (*Oryza sativa* L.) and its Nutrient Uptake

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Abstract

An experiment was conducted to study the yield response and nutrient uptake of rice (BRRI dhan30) to reduced rates of N, P and K from the recommended fertilizer doses (RFD). The experiment was laid out in a randomized complete block design with four replicates. There were ten treatments viz. T₁ (control), T₂ (RFD), T₃ (RFD - 20% N), T₄ (RFD - 40% N), T₅ (RFD - 20% P), T₆ (RFD - 40% P), T₇ (RFD - 20% K), T₈ (RFD - 40% K), T₉ (RFD - 20% NPK) and T₁₀ (RFD - 40% NPK). The recommended fertilizer doses of the crop were 100 kg N, 20 kg P, 40 kg K, 20 kg S and 3 kg Zn ha⁻¹. The highest grain yield (5.10 t ha⁻¹) and straw yield (7.02 t ha⁻¹) were obtained by applying recommended doses of fertilizers which were insignificantly different from those observed in the treatments where N, P and K were reduced at the rate of 20% from the recommended doses. Similar results were also found in case of P, K and S content and uptake by rice plant, while the variation for N was found significant. Overall results indicated that 20% reduction of either N or P or K from the recommended doses would not significantly affect the yield of rice.

Keywords: Reduced fertilization, rice, nutrient uptake

1. Introduction

Agriculture in Bangladesh is dominated by intensive rice cultivation. Globally, rice is the second most important cereal crop in terms of area but as food it is the most important since it provides more calorie than any other cereals. In Bangladesh, rice ranks first in terms of both area and production. Rice is not only the foremost staple food it also provides nearly 40% of total national employment and 48% of total rural employment (Bhuiyan and Karim, 1999). Soil is the principal source of plant nutrients. But nutrient supplying capacity of soils is gradually declining over time due to intensive cropping with high yielding rice varieties. Nitrogen, P and K are the primary nutrients and these deserve special attention because of their large

requirement and positive influence on growth, yield and yield components of crops (Navin *et al.* 1996). However, these important elements have been found to be at imbalanced, excess and/or deficient levels in most agricultural soils of Bangladesh. Continuous and over application of chemical fertilizers accelerates the depletion of soil organic matter and degrades soil physical and chemical properties. Land degradation is a serious problem not only in Bangladesh but also in the world. Some 40% of the world's agricultural land is seriously degraded (Guardian, 2007). Among the worst affected regions, 75% of total land is unfertile in the Central America, one fifth of the total soil is degraded in Africa, and 11% is unsuitable for farming in Asia (Guardian, 2007).

Excessive use of chemical fertilizers is a major factor for environmental pollution. Large scale use of chemical fertilizers has created a potential health hazard, has reduced microbial population and earthworm activities affecting soil health and has reduced utility of water bodies for men, animals and fishes (Smith *et al.*, 1990). In addition, chemical fertilizers are always expensive inputs for crop production, especially in a developing country like Bangladesh. The reduced rates of N, P and K not only maintain soil health for sustainable agriculture but also save part of the cost of crop production. Moreover, this will reduce agricultural runoff and leaching loss of nutrients, which in turn will reduce environmental pollution. Therefore, the present study was undertaken to investigate the effects of reduced rates of N, P and K on yield and nutrient content of rice.

2. Materials and Methods

2.1. Site description

The experiment was conducted at the Research Farm of the Bangladesh Agricultural University during August to December, 2004. The farm is located at the latitude of 24.74° N and longitude 90.50° E and under the Agro-ecological Zone (AEZ) of Old Brahmaputra Floodplain. The experimental area belongs to sub-tropical climate and is characterized by high temperature accompanied by moderately high rainfall during April to September and low temperature during October to March.

The land was formed from old Brahmaputra river borne deposits which is moderately well drained, medium high and Non-calcareous Dark Grey Flood Plain with a silty loam texture and the reaction of the soil is slightly acidic. Organic matter and total N contents were 2.5 and 0.152%, respectively. Available P and S were 14.17 and 13.76 mg kg⁻¹, respectively, whereas exchangeable K and Ca were 0.12 and 6.09 meq 100 g⁻¹, respectively.

2.2. Treatments and design

The experiment was laid out in a randomized complete block design. There were 10 treatments

including one control. The entire experimental area was divided into four blocks representing four replications and each block was sub-divided into 10 plots with raised bunds. The unit plot size was 4 m × 3 m; the plots were separated from each other by 0.5 m bunds (free space). There were 1.0 m drains between the blocks. The treatments were randomly distributed to sub-blocks in each block. The treatment combinations for the experiment were: T₁ (Control), T₂ (Recommended Fertilizer Dose, RFD), T₃ (RFD – 20% N), T₄ (RFD – 40% N), T₅ (RFD – 20% P), T₆ (RFD – 40% P), T₇ (RFD – 20% K), T₈ (RFD – 40% K), T₉ (RFD – 20% NPK), and T₁₀ (RFD – 40% NPK). The recommended fertilizer doses of the test crop BRRI dhan30 were 100 kg N, 20 kg P, 40 kg K, 20 kg S and 3 kg Zn ha⁻¹ (BARC, 2007).

2.3. Fertilizer application, transplanting and intercultural operations

The full doses of P, K, S and Zn were applied using triple super phosphate (TSP), muriate of potash (MP), gypsum, and zinc sulphate, respectively at the time of final land preparation. Nitrogen as urea was applied in three equal splits: 10 days after transplanting, at maximum tillering stage and at booting stage of the crop. The 32 days old seedlings were transplanted in the plots on 12th August 2003. Plant spacing was 20 cm × 20 cm. Intercultural operations such as weeding, pest control etc. were done as and when required. After transplanting 5-6 cm water was maintained in each plot throughout the growth period. There was no infestation of insect pests and diseases in the experimental crop.

2.4. Harvesting and data collection

The crop was harvested at full maturity on December 8, 2003. The harvested crop of each plot was bundled separately and grain yield, straw and biological yields were estimated. After harvesting of the crop, soil samples were collected from each plot at 0-15 cm depth and were analyzed for residual nutrients.

2.5. Chemical analysis of soil and plant samples

The initial soil sample was collected before land preparation from 0-15 cm by means of an auger from 10 different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. The composite sample was air dried, ground and sieved through a 20-mesh sieve and stored in a plastic bag for physical and chemical analysis.

Particle size analysis of soil was done by hydrometer method (Gee and Bauder, 1986). Soil pH was measured by glass electrode pH meter method using soil water ratio 1:2:5 (McLean, 1982). Organic matter content of soil samples were estimated by wet oxidation method (Nelson and Sommers, 1982). The total N of soil sample was determined following micro-Kjeldahl method (Bremner and Mulvaney, 1982). Available soil phosphorus was measured by Olsen method (Olsen and Sommers, 1982) and available S was determined by turbidimetric method. Exchangeable K, Na and Ca of soils were determined by flame photometer on the neutral ammonium acetate extract (Barker and Surh, 1982).

The collected grain and straw samples from each plot were dried in an oven at 65 °C for about 24 hours after which they were ground by a grinding mill. Later the ground samples were sieved through a 20-mesh sieve. The prepared samples were then chemically analyzed for N, P, K and S following diacid digestion procedure (Jones and Case, 1990; Watson and Issac, 1990).

The analysis of variance for various crop characters and also for various nutrients concentrations and nutrient uptake was done following the F-test. Mean comparisons of the treatments were made following the Duncan's Multiple Range Test (DMRT).

3. Results and Discussion

3.1. Grain and straw yield

The grain yields observed in the different treatments ranged from 3.81 to 5.10 t ha⁻¹ and all the treatments showed higher grain yield over the control (Table 1). The highest grain yield of 5.10 t ha⁻¹ was achieved with the application of recommended doses of fertilizers, which was not significantly different from those observed in the treatments where N, P and K doses were reduced by 20% singly. The grain yield obtained with the reduction of 20% N, P and K were 4.88, 4.93 and 4.99 t ha⁻¹, respectively. The findings of the recommended fertilizer doses in producing grain yields are in agreement with the findings of Singh *et al.* (1998) and Asaduzzaman *et al.* (1996). As the recommended fertilizers doses were calculated based on the soil inherent nutrients and crop demand, it is obvious that application of recommended doses of fertilizers will produce a good yield. However, the results revealed that the recommended fertilizer dose and the treatments where 20% N, P and K were reduced from the recommended doses are equally efficient in producing grain yield but this will help to reduce the cost of production. Furthermore, application of fertilizers at reduced rates would help promote the eco-friendly environment.

Like grain yield, application of recommended fertilizers produced the highest amount of straw as well as biological yields, while the straw yield was statistically identical to those observed in the treatments where N, P and K doses were reduced from the recommended doses at the rate of 20% singly (Table 1). The results revealed that application of recommended doses of fertilizers was more effective in producing the highest straw and biological yields. Straw yields were positively and significantly correlated with grain yield (Figure 1a). It is usual that application of adequate fertilizers produces more biomass of crops which is supported by many studies (Azim, 1999; Hoque, 1999).

Table 1. Effect of reduced rates of N, P and K on the yield of rice

Treatment	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Biological yield** (t ha ⁻¹)
T ₁ (control)	3.81 f	4.30 g	8.11 g
T ₂ (RFD*)	5.10 a	7.02 a	12.12 a
T ₃ (RFD-20% N)	4.88 ab	6.50 ab	11.38 bc
T ₄ (RFD-40% N)	4.36 de	5.95 e	10.31 e
T ₅ (RFD-20% P)	4.93 a	6.86 ab	11.80 ab
T ₆ (RFD-40% P)	4.48 de	6.23 d	10.70 de
T ₇ (RFD-20% K)	4.99 a	6.95 a	11.94 ab
T ₈ (RFD-40% K)	4.65 cd	6.33 cd	10.98 cd
T ₉ (RFD-20% NPK)	4.74 bc	6.41 b	11.15 cd
T ₁₀ (RFD-40% NPK)	4.20 e	5.45 f	9.65 f
SE (±)	0.148	0.115	0.266

Figures in a column having common letters do not differ significantly at 5% level of significance

* RFD = Recommended Fertilizer Dose

** Biological yield = grain + straw

Table 2. N, P, K and S content in grain and straw of BRRI dhan30 as influenced by reduced rates of N, P and K

Treatment	% N		% P		% K		% S	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ (control)	1.039 d	0.372 d	0.224 e	0.129 e	0.184 d	1.302 d	0.118 e	0.099 d
T ₂ (RFD*)	1.349 a	0.508 a	0.294 a	0.170 a	0.226 a	1.691 a	0.140 a	0.117 a
T ₃ (RFD-20% N)	1.209 abc	0.460 a	0.288 ab	0.159 ab	0.222 a	1.624 a	0.136 ab	0.111 a
T ₄ (RFD-40% N)	1.147 bcd	0.434 bc	0.273 b	0.154 b	0.204 c	1.543 ab	0.132 cd	0.109 b
T ₅ (RFD-20% P)	1.219 abc	0.465 a	0.286 ab	0.158 ab	0.228 a	1.631 a	0.137 ab	0.112 a
T ₆ (RFD-40% P)	1.178 bcd	0.450 b	0.248 d	0.148 c	0.210 b	1.536 abc	0.133 c	0.110 b
T ₇ (RFD-20% K)	1.256 ab	0.467 a	0.287 ab	0.163 ab	0.221 a	1.553 ab	0.138 ab	0.113 a
T ₈ (RFD-40% K)	1.194 bc	0.451 b	0.273 c	0.155 b	0.200 c	1.497 bc	0.135 abc	0.109 b
T ₉ (RFD-20% NPK)	1.201 abc	0.452 b	0.280 ab	0.156 b	0.217 b	1.551 ab	0.134 c	0.110 b
T ₁₀ (RFD-40% NPK)	1.101 cd	0.403 c	0.245 d	0.139 d	0.192 cd	1.418 cd	0.125 d	0.103 cd
SE (±)	0.063	0.023	0.0025	0.0026	0.0234	0.054	0.0024	0.0019

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

* RFD = Recommended Fertilizer Dose

3.2. Nutrient contents in grain and straw

3.2.1. Nitrogen content

There was significant effect of the different treatments on N concentration of both rice grain and straw (Table 2). The N content in grain varied from 1.04 to 1.35%, and the maximum N content in grain was observed with the application of recommended fertilizers which was statistically similar to those recorded in the treatments where NPK were reduced from the recommended doses at the rates of 20% singly and altogether, respectively. The lowest concentration of N was recorded in the control treatment which was statistically similar to those observed in the treatments.

The concentration of N in straw due to different treatments ranged from 0.37 to 0.51%, where the highest concentration was found in the treatment of recommended fertilizers (Table 2). The difference in N concentrations in straw among the treatments of recommended fertilizers and the treatments where N, P and K were reduced at the rate of 20% singly were insignificant. The grain N contents were always higher in all the treatments than that of straw. Phongpan *et al.* (1988), Azim (1999) and Hoque (1999) also reported similar results.

Nitrogen uptake by grain and straw varied from 39.53 to 68.79 kg ha⁻¹ and 16.04 to 35.66 kg ha⁻¹, respectively. The highest amounts of N uptake by grain, straw and grain plus straw were recorded in the plots where chemical fertilizers were applied as per recommendation (Table 3). A linear relationship between grain yield and total N uptake was obtained (Figure 1b). Phongpan *et al.* (1988) reported that N uptake by rice increased significantly with increasing rates of urea application. Similar results were also noted by Kadu *et al.* (1991).

3.2.2. Phosphorus content

Phosphorus content in grain ranged from 0.22 to 0.29%, while in the straw it varied from 0.13 to 0.17% and P concentration in grain was higher than that in straw in all the treatments (Table 2). The concentrations of P both in the grain and

straw were insignificantly different among the treatments of recommended fertilizers and individual reduction of N, P and K at the rate of 20%. The difference of grain P was not significant among the above said treatments and the treatment where 20% NPK altogether was reduced. It was observed that P content in both grain and straw of rice was the highest with the increasing N, P and K rates (Hoque, 1999; Azim, 1999).

The ranges of P uptake observed in grain and straw were 8.49 to 14.99 kg ha⁻¹ and 5.54 to 11.93 kg ha⁻¹, respectively (Table 3). The P uptake by grain in the treatment of recommended fertilizers was statistically identical to those noted in the treatments of 20% reduction of N, P and K singly. But the straw P was significantly higher over all other treatments. A significant linear relationship between total P uptake and grain yield was observed (Figure 2a). Datta and Gupta (1984) and Subbian *et al.* (1989) stated that total P uptake increased with the increased levels of P.

3.2.3. Potassium content

Potassium content in grain varied from 0.18 to 0.23%, while in straw it was 1.30 to 1.69% (Table 3). The differences of K concentration in grain among the treatments of recommended fertilizers and 20% reduction of N, P and K singly were insignificant. However, the differences of K concentration in straw among the above treatments and the treatments of 40% reduction of N and P singly and 20% reduction of NPK altogether were insignificant. Hoque (1999) showed that K concentration in both grain and straw of rice was the highest with N, P and K application which is in agreement with our findings.

The K uptake by grain and straw varied from 7.02 to 11.52 kg ha⁻¹ and 56.00 to 118.71 kg ha⁻¹, respectively (Table 4). The K uptake in the treatment of recommended fertilizers was insignificantly different to those observed in the treatments of 20% reduction of N, P and K singly and NPK altogether.

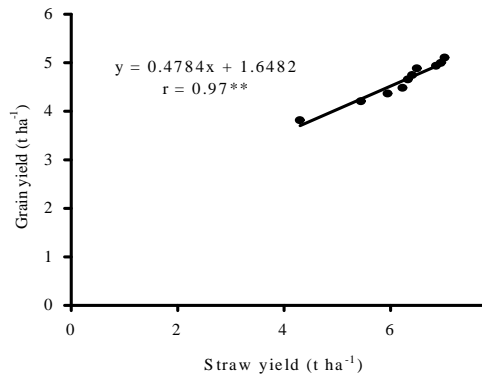


Fig. 1a. Relationship between grain and straw yield

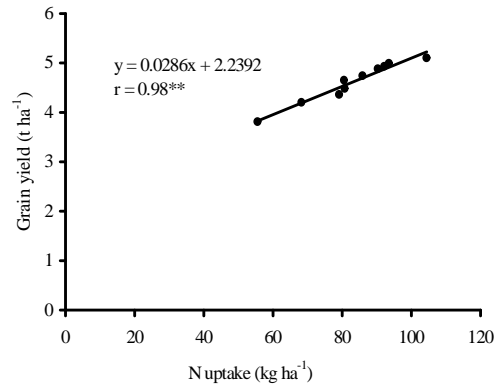


Fig. 1b. Relationship between N uptake and grain yield

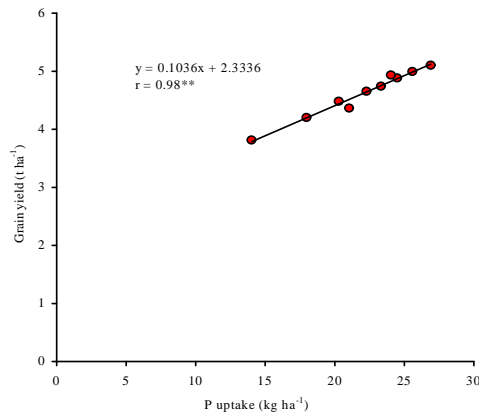


Fig. 2a. Relationship between P uptake and grain yield

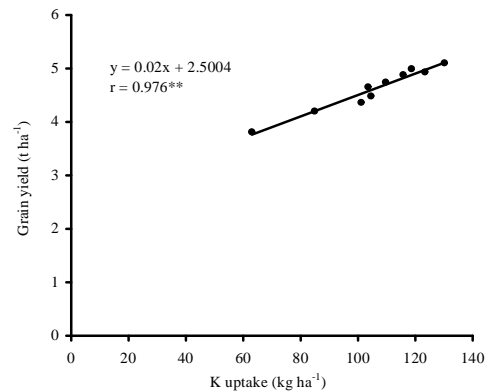


Fig. 2b Relationship between K uptake and grain yield

It was observed that K concentration and uptake was higher in rice straw than in grain in all the treatments. As K concentration, economic yields and biomass were higher in the treatment of recommended fertilizers, total K uptake was the highest in this treatment which was significantly different from all other treatments. A linear relationship between grain yield and K uptake was obtained (Figure 2b).

3.2.4. Sulphur content

The maximum S content in grain and straw were 0.14 and 0.12%, respectively in the treatment of recommended fertilizers, which were insignificantly different with the treatments of 20% reduction of N, P and K singly (Table 3). Similar to S concentration, its uptake by grain,

straw and grain plus straw was also higher in the treatment of recommended fertilizers (Table 4). Islam *et al.* (1990) stated that application of S combined with other nutrients increased the concentration of S in both grain and straw. Similar results were also found by Poongothai *et al.* (1999) and Sakal (1995).

3.3. Post-harvest soil properties

The pH and OM content of the post-harvest soils were not significantly influenced by treatments (Table 5). The pH of the post-harvest soils ranged from 6.4 to 6.7. The pH value of initial soil was 6.7. A decrease in pH value of the post-harvest soils might be due to acidic effect of N, P, K, S and Zn supplied from respective fertilizers.

Table 3. Effect of reduced rates of N, P and K on N and P uptake by BRR1 dhan30

Treatment	N uptake (kg ha ⁻¹)			P uptake (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total
T ₁ (control)	39.53 e	16.04 g	55.58 f	8.49 f	5.54 i	14.03 h
T ₂ (RFD*)	68.79 a	35.66 a	104.41 a	14.99 a	11.93 a	26.92 a
T ₃ (RFD-20% N)	60.22 b	29.90 bcd	90.36 bc	14.03 ab	10.48 cd	24.51 c
T ₄ (RFD-40% N)	52.13 cd	25.84 e	79.17 d	11.91 cd	9.13 g	21.05 f
T ₅ (RFD-20% P)	60.29 b	31.93 bc	92.15 bc	14.10 ab	10.84 bc	24.94 bc
T ₆ (RFD-40% P)	53.33 c	28.03 de	80.74 d	11.09 de	9.21 g	20.30 f
T ₇ (RFD-20% K)	61.22 b	32.30 ab	93.53 b	14.29 ab	11.30 b	25.59 b
T ₈ (RFD-40% K)	52.72 c	28.41 cde	80.55 d	12.48 c	9.82 ef	22.29 e
T ₉ (RFD-20% NPK)	56.93 bc	28.97 be	85.90 cd	13.27 bc	10.06 de	23.33 d
T ₁₀ (RFD-40% NPK)	46.20 d	22.03 f	68.23 e	10.27 e	7.71 h	17.98 g
SE (±)	2.93	1.68	3.44	0.635	0.275	0.492

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

* RFD = Recommended Fertilizer Dose

Table 4. Effect of reduced rates of N, P and K on K and S uptake by BRR1 dhan30

Treatment	K uptake (kg ha ⁻¹)			S uptake (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total
T ₁ (control)	7.02 e	56.00 f	63.02 h	4.49 e	4.24 f	8.73 h
T ₂ (RFD*)	11.52 a	118.71 a	130.23 a	7.14 a	8.21 a	15.35 a
T ₃ (RFD-20% N)	10.80 ab	105.00 bc	115.80 cd	6.62 ab	7.23 c	13.84 cd
T ₄ (RFD-40% N)	8.88 cd	91.93 d	101.20 f	5.77 cd	6.47 d	12.31 f
T ₅ (RFD-20% P)	11.23 a	111.90 ab	123.40 b	6.75 ab	7.72 b	14.22 bc
T ₆ (RFD-40% P)	9.43 bc	95.16 d	104.60 ef	5.92 bcd	6.85 c	12.77 ef
T ₇ (RFD-20% K)	11.03 a	107.80 bc	118.74 bc	6.87 a	7.85 ab	14.72 ab
T ₈ (RFD-40% K)	9.51 bc	94.04 d	103.60 ef	6.29 abc	6.89 c	13.19 de
T ₉ (RFD-20% NPK)	10.29 abc	99.42 cd	109.71 de	6.36 abc	7.05 c	13.41 cd
T ₁₀ (RFD-40% NPK)	8.06 de	76.87 e	84.93 g	5.24 de	5.64 e	10.88 g
SE (±)	0.638	4.11	3.14	0.368	0.184	0.388

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

* RFD = Recommended Fertilizer Dose

Table 5. Effect of reduced rates of N, P and K on residual soil nutrients

Treatment	pH	Organic matter (%)	Total N (%)	Available P (mg kg ⁻¹)	Exchangeable K (meq 100 g ⁻¹ soil)	Available S (mg kg ⁻¹)
T ₁ (control)	6.68	2.39	0.149 a	11.00 e	0.103 c	10.91 e
T ₂ (RFD*)	6.41	2.13	0.135 c	15.02 a	0.128 a	15.06 a
T ₃ (RFD-20% N)	6.47	2.25	0.141 b	14.74 ab	0.123 a	14.51 ab
T ₄ (RFD-40% N)	6.52	2.27	0.143 b	13.88 bc	0.118 b	13.93 b
T ₅ (RFD-20% P)	6.54	2.22	0.136 c	14.22 ab	0.124 a	14.33 ab
T ₆ (RFD-40% P)	6.56	2.24	0.140 bc	12.90 d	0.116 b	13.23 c
T ₇ (RFD-20% K)	6.51	2.23	0.139 bc	14.27 ab	0.122 a	14.35 ab
T ₈ (RFD-40% K)	6.57	2.26	0.141 b	13.92 bc	0.115 b	13.44 c
T ₉ (RFD-20% NPK)	6.58	2.28	0.142 b	13.99 bc	0.119 b	14.25 ab
T ₁₀ (RFD-40% NPK)	6.59	2.29	0.144 ab	12.37 d	0.106 c	12.21 d
Initial soil	6.71	2.50	0.152	14.17	0.115	13.76
SE (±)	NS	NS	0.0023	0.396	0.0027	0.414

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

* RFD = Recommended Fertilizer Dose

Swarup and Singh (1994) reported that application of fertilizers decreased the soil pH. The OM content of the post-harvest soils varied from 2.13 to 2.39% and it tended to decrease in the soils treated with more fertilizers. This could be because application of chemical fertilizers accelerates the decomposition of organic materials in soil. Moreover, in the tropical climate soil microorganisms are more active in the decomposition of soil organic matter. Similar results were also reported by Razzaque (1996) and Azim (1999).

Residual soil N, P, K and S were significantly influenced by different treatments (Table 5). Soil treated with more chemical fertilizers showed a slight decrease in the total N content of post harvest soils. The highest total N content (0.149%) was obtained in the control treatment while the lowest (0.135 %N) was in the treatment of recommended fertilizers. The results revealed that rice cultivation with chemical fertilizers had a decreasing effect on the total N content of the post-harvest soils. Rabikowsha *et al.* (1993) reported that addition of NPK fertilizers decreased the total N content of soil. The highest amount of residual P, K and S were recorded in the treatment where recommended doses of fertilizers were applied, which was statistically identical to those noted in the treatments of 20% reduction of N, P and K singly from the recommended doses of fertilizers. The lowest amount of residual P was observed in the control treatment. It was observed that soils treated with increasing rate of phosphatic fertilizer gave higher values of residual phosphorus. Bhuiyan and Saha (1992) found that available soil P content increased substantially due to application of P fertilizer in each crop.

4. Conclusions

Maximum grain and straw yields of rice were obtained in the treatment where recommended fertilizers were applied but these yields did not vary significantly with the yield observed in the treatments with the reduction of either N or P or K at the rate 20% from the recommended doses. Application of fertilizers at reduced rates obviously helps promote the eco-friendly environment via reducing and limiting the sources and amount of environmental pollution from agricultural runoff and leaching. Ample supply of nutrients using

organic sources with the supplementation of inorganic fertilizers would help maintain soil health and sustain its productive capacity and thus ensure a sustainable environment.

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