Fertilizer management effects on fertility of old Brahmaputra flood plain soil under rice cultivation

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Abstract: An experiment was carried out during aman season of 2012 in the permanent experimental field of the Department of Soil Science, Bangladesh Agricultural University (BAU) Farm, Mymensingh. The objectives of the present study were to observe the impacts of 34 years of fertilization on yield of BRRI dhan 49 and soil properties. The experiment was laid out in a randomized complete block design with three replications. There were 6 treatments viz, 0 (control), N, NP, NPK, NPKSZn and NFYM. The experiment covered the period from 16 July to 22 December 2012. Due to long continued cultivation of wet land rice, the amount of organic matter and total N increased in soil over initial level. Soil pH decreased in control, N and NP treated plots but remained static in NPK, NPKSZn and NFYM treated plots. The P content of soil increased in P treated plot over control. The available S status increased in soil due to NPKSZn and NFYM treatments. The status of K reduced very strikingly over initial values in all treatments.
Keywords: Fertilizer management, Soil chemical properties, Grain and straw yields.

Introduction

Bangladesh is a densely populated agro-based country with rice as main staple food. Rice is the staple food for more than half of the world's population. The crop influences the livelihood and economics of several billion people, and hundreds of millions it is the only thing between them and strvation (IRRI, 2006). Total rice production in Bangladesh was 10.32 million tons in the year 1975-76 when the countries population was only 79.90 millions and cultivated rice area was 10.32 million ha^{-1} (BBS and DAE, 2007). Rice provides 23% of the global human per capita energy and 16% of the per capita protein. Rice is grown in over 8.08 million hectare under the various schemes subject to irrigated, rainfeed and deep water conditions in three distinct seasons, namely Aus, Aman and Boro. Among the three crops, aman rice covers 47.73% of total rice and it contributes to 33.39% of the total rice production (BBS, 2008).

Fertilizers are essential parts of modern farming, with about 50% of the world's production being attributed to fertilizer use (Pradhan, 1992). Fertilizer use in different countries of the region has increased considerably with maximum (509 kg $ha^{-1}yr^{-1}$) in the republic of Korea as against only 102 $kgha^{-1}yr^{-1}$ in Bangladesh (Karim *et al.,* 1994). Fertilization and manuring of our soils have been increased over the period and farmers are supposed to use these inputs intensively for sustained crop production. The farmers of Bangladesh use only about 102 kg nutrients ha^{-1} annually (70 kg N+ 24 P_2O_5 + 6 kg K_2O + 2 kg S and Zn), where the crop removal is about 200 $kgha^{-1}$ (Islam *et al.,* 1994). The increasing land use intensity without adequate and balanced use of chemical fertilizers and with little or no use of organic manure have caused severe fertility deterioration in our soils resulting in stagnating or even declining of crop productivity. The yield limiting nutrients for rice production in Bangladesh known so far are N, P, K, S and Zn of which the three major elements like N, P and K are the most important in term of their potentiality for the reason of both the crop yields inclination or declination. In most soils of our country have severe deficiency of nutrients like N, P and K have been identified (Islam *et al.,* 1990; Mandal *et al.,* 1992; Islam and Hossain, 1993).

Ali (1994) stated that an amount of 1054 tons of nutrients (N, P and K) is being lost every year from arable land of Bangladesh. The phenomenon of nutrient depletion or mining from soils risking the prospect of increased food production has been highlighted and well documented by the FAO in recent years (Pradhan, 1992). Fertile soil is the fundamental resource for crop production; its maintenance is a pre-requisite for long-term sustainable crop productivity.

The present research work was therefore, undertaken to evaluate the long-term effects of manures and fertilizers on the yield of BRRI dhan 49 and to observe the long-term effect of manure and fertilizers on soil chemical properties.

Materials and Methods

The experiment was carried out with soil samples collected from permanent manurial experimental field of the Department of Soil Science, Bangladesh Agricultural University (BAU) farm, Mymensingh. The soil of the plots developed on the alluvial deposit of the Old Brahmaputra. The soil forming processes of the field was mainly influenced by surface water and ground water (Abedin, 1990). There were 10 treatment combinations viz. control, N, NP, NK, NPK, NS, NZn, NSZn, NPKSZn and FYM. The fertilizer doses used for each crop were 90 kg N ha^{-1}, 20 kg P ha^{-1}, 19 kg K ha^{-1}, 30 kg S ha^{-1}, 8 kg Zn ha^{-1} and 5000 kg cowdung ha^{-1}. Out of these 10 treatments 6 treatments were considered viz. Control, N, NP, NPK, NPKSZn and NFYM. Soil samples at depth of 0-10, 10-20 and 20-30 cm were collected from three spots of three replicated plots of the selected treatments.

Soil pH was measured by glass electrode pH meter using soil: water suspension of 1:2.5 as described by Jackson (1962). Organic carbon of the soil samples was determined by wet oxidation method as outlined by Page (1982) and the organic matter was calculated by multiplying percent organic carbon with the conventional Van Bemmelin factor of 1.73. Total nitrogen of soil was estimated by semi microkjeldahl method (Page *et al.,* 1982). Available phosphorus was extracted from soil by shaking with 0.5 M $NaHC0_3$ solution at pH 8.5 following the method of Olsen *et al.* (1954). The amount of exchangeable potassium extracted from the soil with 1N NH_4OAc solution at pH 7.0 (Black, 1965) was determined by flame-photometer and, comparing the reading to the standard curve prepared for K. The soil was extracting with $CaCl_2$ solution (0.15%) as described by Page *et al.* (1982) and the S in the extract was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCI) and $Bacl_2$

crystals. The intensity of turbidity was measured by Spectrophotometer at 420 nm wave length. The amount was calculated by comparing the colorimetric readings with a standard curve.

Analysis of variance of the measured parameters was performed using MSTAT-C and treatment means were compared using Duncan's multiple range test (DMRT) at 5% probability level.

Results

Soil pH: The results on pH of soils collected from different depths and treatments of the permanent manual experiment conducted by the department of soil science of Bangladesh agricultural university farm are presented in the Table 1 with initial value. The present study was conducted after 34 years of starting this permanent experiment in 1978. During this period a change in pH of soil has been occurred compared to initial pH of 6.8. In general, the pH of surface (0-10 cm) soil was lower than sub-surface (10-20 cm) soils. The value further increased as the depth increased from 10-20 cm to 20-30 cm. In surface soil it varied from 6.23-6.93 where as at 10-20 cm depth it ranges from 6.75-7.21 and at 20-30cm it varied from 7.0-7.24. Different treatments also showed some influences on soil pH at different depths. Comparing the effects of different treatments it appears that the surface soil pH of N treated plot was lower than other treatments. It was followed by NP treatment. In lower depths the treatments did not follow any definite trends although highest value was always found in NPK treated plot. The previous experiments conducted at Bangladesh Agricultural University farm by different workers showed that a considerable amount of bases are leached out each year though weathering of soils. The lower values of pH as found in surface soil might be possible for this loss of bases from surface soil. In addition to this, the ammonium ion produced from applied N fertilizers and released though mineralization of organic matter, increased the acidity during drying of soil sample due to oxidation of ammonium to nitrate by releasing proton (H^+).

Table 1. Soil pH, Soil organic matter (%) at different depth of soil during the study period

Treatments	pH			Organic matter (%)		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Control	6.70 bc	6.75 c	7.00 c	2.07 c	0.880 b	0.500 b
N	6.23 d	6.75 c	7.08 bc	2.90 a	1.460 a	0.820 a
NP	6.52 c	7.04 ab	7.09 b	2.84 a	1.450 a	0.840 a
NPK	6.93 a	7.21 a	7.22 a	1.98 c	0.710 b	0.530 b
NPKSZn	6.81 ab	6.88 bc	7.08 bc	2.68 b	1.420 a	0.800 a
NFYM	6.77 ab	6.88 bc	7.24 a	2.58 b	1.320 a	0.81 a
$LSD_{0.05}$	0.181	0.229	0.081	0.115	0.199	0.115
CV (%)	1.04	1.26	0.51	1.94	6.48	5.44
Initial	6.8	-	-	1.25	-	-

Table 2. Soil Nitrogen content (%), Soil Phosphorus content (ppm), Soil Sulfur content (ppm) and Soil Potassium content (ppm) at different depth of soil during the study period

Treatments	Soil N (%)			Soil P (ppm)			Soil S (ppm)			Soil K (cmol K kg^{-1})		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Control	0.16 a	0.084 b	0.050 b	15.80 b	18.10 b	16.40 c	10.01d	9.790 d	7.810 bc	0.080 ab	0.087 a	0.092 b
N	0.17 a	0.084 b	0.058 ab	13.15 c	16.75 c	15.40 d	12.89 bc	10.45 bc	8.470 a	0.085 a	0.087 a	0.102 a
NP	0.17 a	0.076 b	0.056 ab	20.80 a	25.30 a	21.80 a	13.31 b	10.88 b	8.000 b	0.085 a	0.089 a	0.092 b
NPK	0.12c	0.065 b	0.050 b	21.10 a	16.30 c	20.80 b	12.43 c	10.01 cd	7.680 cd	0.072 b	0.077 b	0.089 b
NPKSZn	0.13 bc	0.112 a	0.059 a	16.60 b	16.20 c	13.90 e	14.30 a	11.44 a	7.540 d	0.062 c	0.072 b	0.095 ab
NFYM	0.15 ab	0.076 b	0.054 ab	14.00 c	14.80 d	12.40 f	14.20 a	10.05 cd	7.520 d	0.085 a	0.087 a	0.092 b
$LSD_{0.05}$	0.025	0.025	0.008	1.57	1.08	0.749	0.487	0.459	0.199	0.008	0.008	0.008
CV (%)	4.87	3.01	2.17	3.62	2.36	1.74	1.48	1.72	0.99	4.64	2.56	1.56
Initial	0.06	-	-	9.00	-	-	8.80	-	-	0.200	-	-

Same superscript in row are not significantly different ($P<0.05$), LSD = Least Significant Difference, CV (%) = Co-efficient of Variatio

Soil Organic Matter (OM): The results of organic matter have been presented in the Table 1. In 1978 the organic matter content of soils of the experimental field was 1.25%. Due to continuous cultivation of wet land rice for the last 34 years a remarkable change in the status of organic matter has been occurred. In1978 only the soils of surface layer were analyzed for organic matter hence results of organic matter of soils from lower depths is not available. In general, the status of organic matter increased over the initial content during this period. A gradually decreasing trend of organic matter was observed with the increase in soil depths. At surface soil it varied from 1.98-2.90% irrespective of treatments. The highest and the lowest values were obtained due to N and NPK treatments respectively. The treatment NP was more close to N and remarkably higher than other treatments. The effects of NPKSZn and NFYM treatments were almost identical and better than NPK and control treatments. At 10-20 cm depths the effects of the treatments N,NP, NPKSZn and NFYM were almost identical with higher values in N treated plot followed by NP. The status of NPK and control was remarkably lower than other treatments. Between these two treatments NPK treatments was inferior to control. At 20-30cm depth, the treatments did not show remarkable variation between them except control and NPK. Comparing the status of organic matter of different depths it appears from the results that the rate of decrease in organic matter content for each 10cm variation was almost 50% up to 30cm, the lowest depth under study.

Total Nitrogen: The total nitrogen content of surface soil varied from 0.12-0.17% irrespective of treatment combinations (Table 2). It decreased to 0.065-0.112% in the sub-surface (10-20 cm) soils. The concentration further decreased as the soil depth increased. The variation between the treatments and the depths of the soil was mainly associated with the organic matter content of soil of different depths and treatment. The initial status of organic carbon and total N was 0.72 and 0.06%, respectively. During this period the organic carbon content have been increased remarkably by about 0.28-0.81% over the initial level. This increase in organic matter content of soil was probably due to long continued wetland rice cultivation.

Available Phosphorous: The results of available Phosphorous have been presented in the Table 2. The initial Phosphorous concentration of soils of the experimental plot was 9.0 ppm. Intensive cropping and fertilization over the last 34 years brought about remarkable change in P content of soils. In the present study, the soils of P treated plot showed higher values than the P control plots ranging from 12.4-25.3 ppm irrespective of depths as well as treatments. In surface soil (0-10cm), lowest value was found in N treated plots followed by NFYM treatment and then control plots. The P concentration of NPKSZn treated plot was higher but very close to control. The status of NP and NPK treated plots was very close to each other and much higher than other plots.

Available sulfur: The results of available Sulfur have been presented in the Table 2. Intensive cropping and fertilization brought about a change in available S content of soils of different depths but it was not as remarkable as was found in case of organic matter N and P content of soils. In 1978 the S content of the experimental plot was almost 8.8 ppm in surface layer. Due to fertilization it increased by about 1.2-5.5 ppm over initial level irrespective of treatments. In 10-20cm depth the status varied from 9.79-11.44 ppm soil which was more close to surface soil than the soils from lower depths. A remarkable decrease in available S content was found in 20-30cm depths compared to the upper depths. These vertical changes in S content of soils showed a close relation of S with the organic matter content that was also remarkably decreased at the 20-30 depths. The continuous application of N and NP slightly increase the S content over control plot but the addition of K with NP did not show any effect an available S content of soil in surface layer. The status of available S of soils under NPKSZn and NFYM treatments was almost identical and higher than other treatments although it was not remarkable. The increase in available S content of soil was probably the effects of soil organic matter that was also increased over the years due to long continued wet land rice cultivation.

Exchangeable Potassium: The results of available Potassium have been presented in the Table 2. Unlike organic matter, N, P and S the status of exchangeable K strongly decreased compared to initial status due to long intensive cultivation of rice for the last 34 years. In 1978 the exchangeable K of the soils of the experimental plot was 0.20 cmol K kg^{-1} soil which decreased to .062-.08 cmol K kg^{-1} soil in surface layer (0-10cm). This shows almost a reduction of 57.5-69% over the initial status. The highest reduction in exchangeable K was noticed in NPKSZn and NPK treatments although there was continue input of K. The level of k gradually increased with the increase of soil depths up to 30cm. The treatments did not show any remarkable effect in different depths.

Grain and Straw yield: The grain and straw yields of rice showed wide variation due to different treatment combinations (Figure 1). As expected, the yields of control plot were the lowest. Application of N alone increased the grain and straw yields by 1.43 and 1.56 times over the control. Addition of P with N did not bring any beneficial effect over N alone. However, the addition of K with NP increased the grain and straw yields of rice over N and NP treatments. A strong increase in yields over all treatments was obtained due to application of S and Zn with NPK. The effects of the treatment NFYM was higher than NP treatment but lower than N, NPK and NPKSZn treatments. However, it's effect was more close to N than other treatments in both grain and straw yields. It appears from the results that after 34 years of continuous fertilization and cropping yield the effects of N were more prominent. It was followed by K and then S and Zn.

Discussion

This permanent experiment was started in 1978 in silt loom paddy soils of Bangladesh Agricultural University farm with rice-rice cropping pattern in order to observe the effects of long-term continuous fertilization and cropping on rice yields and soil properties. During this period a number of almost 70 crops have been harvested from the field. Continuous cropping and fertilization during the last 34 years has brought about a remarkable change in soil properties. In general, the pH of surface soil slightly decreased over the initial soil pH of 6.8 except NPK, NPKSZn and NFYM treatments. It appears that total N content of soil increased remarkably over the periods. This increase in total N and organic matter might have an effect on the observed pH of soil. Literature shows that oxidation of NH_4^+ under oxidized condition releases proton (H^+) that lower pH of soil. Mian *et al.* (1991) conducting an experiment at Bangladesh Agricultural University farm reported a severe losses of bases through weathering of surface soils. These losses of bases decreased the pH in surface soil and increased in sub-surface soil. Chowdhury (1990) also observed similar results.

The wet land cultivation of rice for long period have resulted an increase in organic matter and total N content of soils. The lower rate of oxidation of organic matter by microbes under anaerobic situation was the main reason for the obtained increase in organic matter and total N in soils, although the status was low (as graded by the BARC, 2005). The status of available P varied from medium to optimum but S content was low irrespective of treatments. Application of P fertilizer increased the status of available P in all depths. It is almost established that a part of applied P fertilizers remain unused in soils. The increase in P status in P treated plots over the initial level was probably the effects of residues P fertilizer and increase in organic matter. Sulphur fertilization over long period did not bring any remarkable change in available S content of soil although the status of surface soil was higher than initial status. A strong reduction in exchangeable K content of soils was noted irrespective of treatments. At the time of starting this experiment the soil contained 0.20 cmol K kg^{-1} soil. The status decreased to . 06-0.085 cmol K kg^{-1} soil in the top 0-10 cm after 34 years of fertilization and cropping. The highest depletion was noted in NPK and NPKSZn treated plot. An amount of 20kg K/ha was applied to each crop through fertilization but the requirement of crop was much higher. As a result; the crop taken up more native K from soils reserve through it's own mechanism to meet the requirement. This exhaustion of soil K was more in plots where biomass yield was more. This is evidenced from the lowest status of K in NPK and NPKSZn treated plots. In addition to higher uptake than addition, a significant amount of K is lost from soil with percolation water through weathering of soil minerals. This loss of K also had significant contribution to the strong reduction of K status of silt loom soil of Old Brahmaputra Flood Plain.

Due to cultivation of wet land rice the amount of organic matter of soil increased over initial level. Soil pH decreased in control, N and NP treated plots but remained static in NPK, NPKSZn and NFYM treated plots. The P content of soil increased due to application of fertilizers. The K content of soil severely decreased due to long continued cultivation of wet land rice with low dose of K. The effects of N were more prominent on grain yield. The performance of K was lower than N but higher than P and S.

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