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Effects of long-term intensive fertilization on yield and nutrient uptake by rice

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ABSTRACT

An experiment was carried out during boro season of 2009 in the permanent manurial experimental field of the Department of Soil Science, Bangladesh Agricultural University (BAU) Farm, Mymensingh. The objectives of present research were to see the impacts of 30 years fertilization on yield contributing characters, yield and nutrient uptake by boro rice. The experiment was laid out in a randomized complete block design with three replications. There were ten treatment combinations viz, Control, N, NP, NK, NPK, NZn, NS, NSZn, NPKSZn, N+FYM. The experiment covered the period from 09 February to 28 May 2009.The results indicated that the yield contributing characters and yields of BR11 rice were significantly increased due to different treatments. Treatment NPKSZn exerted strong influence on yield contributing characters viz. plant height, number of tillers hill^{-1}, dry matter yield, number of grain panicle^{-1}, number of filled and unfilled grains panicle^{-1} and 1000 grain weight. Considering the yield contributing parameters and yield, the NPKSZn treatment was found more suitable than others. The phosphorus, potassium and sulphur content in BR11and their uptake were highest due to the treatment NPKSZn although some variations were found in all other treatments.

INTRODUCTION

The cropping patterns of Bangladesh are mainly rice based. Rice is the main food crop and grown in all the three crop growing seasons. However, the yield of rice is low and the average yield is 2.33 t ha-1 (BBS, 2004). In Bangladesh, the demand of rice production is increasing day by day due to its huge population size which is increasing at an alarming rate. At the same time, per capita cultivable land is also decreasing. That is why; the major goal of the country is to increase the production of rice to meet up the demand for food.

Some important nutrients like nitrogen, phosphorus, potassium, sulphur and zinc play a vital role in rice production. Among these nitrogen, phosphorus and potassium are considered as primary nutrient elements in terms of their potential for causing both increase and decrease in rice yield. In most soils of the country, severe deficiency of nutrients like N, P and K have been identified (Islam et al. 1990; Islam and Hossain, 1993). Long-term use of chemical fertilizer creates some fertility problems through soil exhaustion as well as through interaction with other elements (Rahman and Abedin Mian, 1997). Soil particles become compact and not able to retain nutrients due to repeat and overuse of chemical fertilizers (Deka Medhi and De Datta, 1996)

The wide variation in soil moisture in different periods of the year and the methods of rice cultivation either in dry or in wetland conditions bring about a change in the nutritional properties of soil (Abedin Mian, 1988; Abedin Mian and Eaqub, 1984).

Farmers of Bangladesh started continuous application of chemical fertilizers from early 1960 to increase the production of rice and other agricultural crops. They have been using high inputs, modern technologies and intensive cultivation of high yielding varieties (HYVs).

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Despite, they are not getting expected level of production. This indicates that fertility status of soil has been depleted due to long-term fertilization as well as changes in soil ecology. Somebody says that specific nutrient elements are either increasing or decreasing probably due to continuous application of manures and fertilizers in their field. For this reason, the soils of Bangladesh are nutritionally imbalanced. Continuous use of inorganic fertilizers alone to soils had a deleterious effect on soil productivity and a steadily declining trend in rice productivity is associated mainly with loss of inherent soil fertility (Nambiar et al., 1998).

The problem of nutrient deficiencies as well as nutrient mining caused by intensive cropping with high yielding varieties of rice and nutrient imbalance can be minimized by Judicious application of nutrients through organic manures or chemical fertilizers (Pradhan, 1992).

The farmer of our country are suggested to apply fertilizer and manure in all crops to increase yield in ordered to meet the demand of ever increasing population of our country. There are reports that the crop yields in our country have been stagnated or declined. But the reasons for this situation are not properly identified. As the fertilizers are chemical substances, they exert influence on physical, chemical and biological properties of soil as well as yield of crop. But, information on the after effect of continuous fertilization on yield and nutrient uptake is not yet properly known. Under these circumstances, the present piece of experiment has been formulated during boro season of 2009 under irrigated conditions with a view to finding out the effect of long-term fertilization on yield contributing characters, yield and nutrient uptake by boro rice grown after 30 years of intensive fertilization and manuring.

MATERIALS AND METHODS

Experimental site and soil

The experiment was conducted in the permanent manurial experimental field of the Department of Soil Science at Bangladesh Agricultural University (BAU) farm, Mymensingh during the boro season (09 February to 28 May) of 2009. Topographically the area was slightly undulating but the experimental plot was fairly leveled. It was above normal flood level but sometimes the plot remained flooded for short time by rainwater during monsoon season.

The soil of the plot was typical rice growing silt loam developed from the alluvial deposits of the river Old Brahmaputra. The soil forming processes of the field was mainly influenced by surface and ground water (Abedin Main, 1990). According to the report of the Department of Soil Survey (1967-68) the general soil type of the field was “Non-calcareous Dark Grey Floodplain Alluvium” and the soil series was sonatala silt loam. It belongs to the agro-ecological zone of “Old Bhahmaputra Flood Plain”. The pH of the soil of the study area was 6.8, organic carbon was 0.86% and total nitrogen was 0.08 % with 8.0 mg kg-1 available phosphorus and 0.28 cmol kg-1 available potassium (HSTL Report 1, 1983).

Climatic condition of the experimental area

The climate of the experimental area is characterized by high temperature accompanied by moderately high rainfall during kharif season (April to September) and low temperature in the rabi season (October to March). In rabi season, temperature is generally low and there is plenty of sun shine. The atmospheric temperature tends to increase from February as the season proceeds towards kharif season.

The experiment

The experiment was laid out in randomized complete block design with three replications. The whole experimental field was divided into three blocks which represented three replications of the experiment. Each block was subdivided into ten unit plots for placement of ten treatments of the experiment. The total number of unit plots of the experiment was 30. The size of the unit plot was 11 m x 6 m (66 m^2). The unit plots were separated from each other by earthen ails of 25 cm width and 10 cm high. There was 50 cm width and 10 cm deep irrigation channel between the blocks.

Treatments

The experiment comprised of ten different treatment combinations of manure and fertilizers namely, control, N, NP, NK, NPK, NZn, NS, NSZn, NPKSZn and N + FYM. The doses and sources of different nutrients and FYM: used for boro rice were as follows:

Nutrient element	Dose	Source
N	70 kg ha $^{-1}$	Urea
P	20 kg ha $^{-1}$	TSP
K	19 kg ha $^{-1}$	MP
S	30 kg ha $^{-1}$	Gypsum
Zn	5 kg ha $^{-1}$	Zinc oxide
FYM	5 t ha $^{-1}$	Decomposed cowdung

Cultural operations

The cultural operations carried out in the fields at different times are shown in Table 1.

Table 1
Cultural operations done in the experimental field.

Cultural operations	Date
1. First ploughing in the field	15.01.09
2. Second ploughing and laddering	20.01.09
3. Third ploughing	30.01.09
4. Fourth ploughing, laddering and removal of plant residues and stubbles	01.02.09
5. Fifth ploughing (final), application of fertilizers (1/3 urea and full doses P, K, S, Zn and FYM) and laddering	08.02.09
6. Transplantation of seedlings	09.02.09
7. Irrigation	15.02.09
8. Gap filling of the experimental plot	20.02.09
9. Weeding	22.02.09
10. Second split application of urea	12.03.09
11. Third split application urea	31.03.09
12. Harvesting	28.05.09

Spraying of insecticides

There was no attack of insect during the growth period hence; no insecticide was applied to the field.

Harvesting

The crop was harvested at maturity on 28 may2009 and threshed plot wise.

Collection of data on yield components

Data were collected and recorded on a) Plant height, b) Number of tillers hill $^{-1}$, c) Dry matter yield, d) Number of filled grains panicle $^{-1}$, e) Panicle length, f) 1000 grain weight, g) Grain yield, h) Straw yield according to the standard procedure. .

Crop harvest

The crop was harvested when 80-90% of the grains were turned into straw colour. The crop was cut at the ground level, bundled plot-wise and brought to the threshing floor. Grain and straw obtained from each plot were dried and weighed carefully. The yields were expressed as t/ha on 14% moisture basis.

Analysis of grain and straw

Sample preparation

The collected grain and straw samples were ground by means of a grinding machine after dried in an oven at 65°C for about 48 hours. The prepared composite samples were stored into paper bags for chemical analysis.

Digestion of sample with nitric-perchloric acid

For the determination of P, K and S, 0.5 g of oven-dried ground plant sample (grain and straw) was taken in semi micro-Kjeldahl flasks. 10 ml of di-acid mixture ($HN0_3$:$HCl0_4$ in ratio 2:1) was added into the flask. Then the flask was heated at a low temperature and gradually raised to 200°c. The content of the flask was boiled until they became clear and colourless. The digest was allowed to cool transferred into a 100 ml volumetric flask and the volume was made up to the mark with distilled water.

Determination of phosphorus, potassium and sulphur

Phosphorus

Five ml of acid digest was taken into a 50 ml volumetric flask. 10 ml ammonium molybdate and 2 ml of stannous chloride solution were added to the flask. The volume was made up to the mark with distilled water and the P content in the extract was determined by spectrophotometer.

Potassium

Five ml of extract of grain sample and 10 ml extract of straw samples were taken to a 50 ml volumetric flask. Volume was made with distilled water and the K content in the extract was measured by flame photometer.

Sulphur

Sulphur was determined by using 10 ml digest of both grain and straw from 100 ml extract and readings were taken by spectrophotometer at 420 nm of wave length.

Nutrient uptake

The nutrient contents were determined and from the amount of nutrients uptake were calculated after chemical analysis of grain and straw samples by the following formula of Jackson (1965).

$$\text{Nutrient uptake}(\text{kg ha}^{-1}) = \frac{\text{Nutrient content}(\%) \times \text{Yield}(\text{kg ha}^{-1})}{100}$$

Statistical analysis

The analysis of variances for different yield contributing characteristics, yield and nutrient uptake were done following the ANOVA technique and the mean results in case of significant F-value were adjudged by the Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Yield contributing components

Number of tiller hill^{-1}

The results demonstrated that the number of tillers increased due to different treatments over control but it varied remarkably between the treatments (Figure 1). In control plot the number of tiller was 8.86. It increased to 9.60 when only nitrogen was added. Addition of either P or K with N increased the number of tiller over N alone but it was not significant. Application of S with N increased the tiller over N but addition of Zn failed to show any effect. An increase in tiller number was found over N, NP, NK, NS, NZn and NFYM due to combined addition of N, P and k. The number of tillers due to NSZn and NPKSZn was higher than other treatments but the number were very closed to NPK treatment. The effect of NFYM was not found encouraging.

Plant height

Like the tiller number, the height of rice plant in the permanent experimental plot was also influenced remarkably due to different treatment combinations (Figure 2). Application of N alone and incombination with P and K increased the plant height over control but the increase was not very encouraging over N alone. A significant increase in plant height was found due to combined application of N, P and K. Application of S and Zn also showed an effect on plant height but lower than NPK treatment. The maximum height of rice plant (97.66 cm) was obtained due to application of NPKSZn this was followed by NFYM and then NPK treatments. The minimum height (65.21 cm) was recorded in control.

Dry matter yield

Dry matter yield of rice plant determined at different growth stages have been presented in Table 2. The treatment under study showed their remarkable influences on dry matter yield. Application of N alone could not influence the yield remarkably over control. But P in addition to N show some influence on dry matter yield. K alone in presence of N also did not show any effect over N. However, a slight beneficial effect was found, when N, P and K fertilizers were applied together. Addition of S, Zn and SZn with N fail to show remarkable effect over N. The treatment NPKSZn showed its superiority on dry matter yield at all stages of growth, although it was not very remarkable. Farmyard manure also failed to show encouraging effect on dry matter yield. An observation over the results revealed that dry matter yield of rice showed an increasing trend with the passes of time from transplanting to harvest.

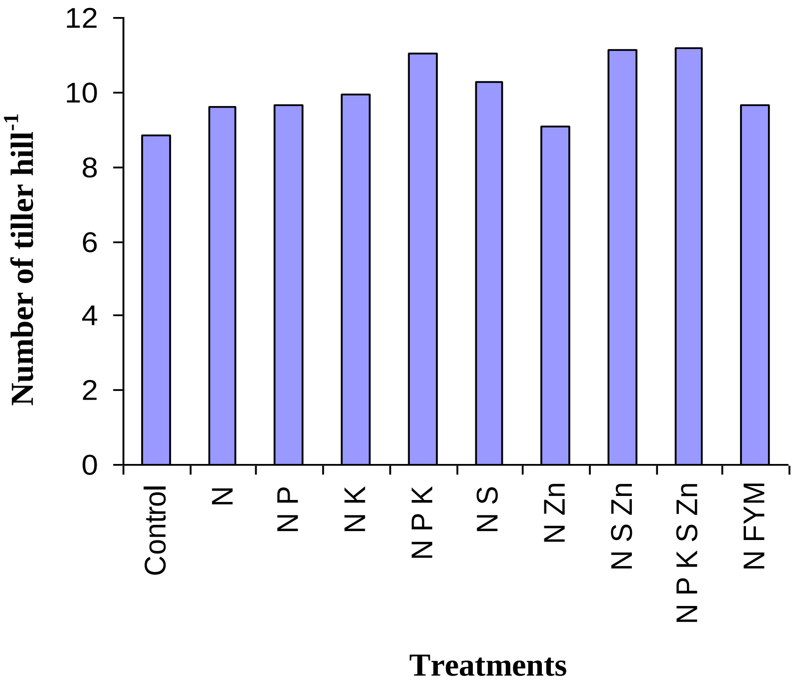

Figure 1
Number of tiller hill^{-1} of Boro rice at harvest.

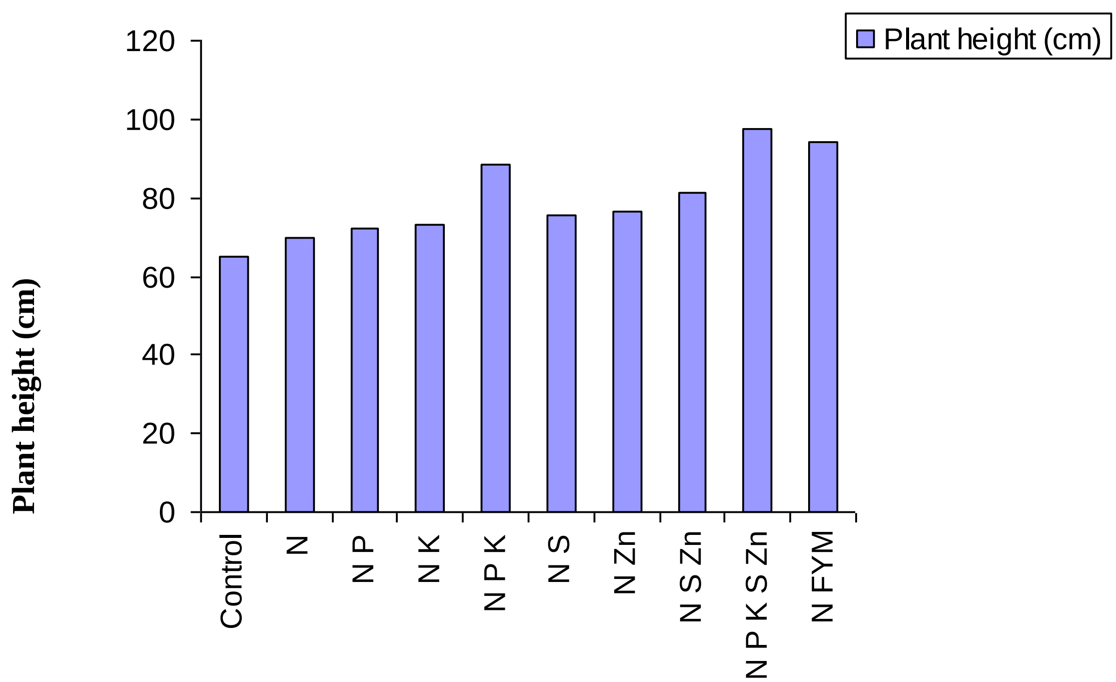

Figure 2
Plant height (cm) of Boro rice at harvest.

Table 2
Dry matter yield of BR11 rice at different growth stages.

Treatment	Dry matter yield (g)		
	45 DAT	60 DAT	75DAT
Control	5.15 f	6.98 f	8.78 f
N	5.24 ef	8.21 e	9.25 ef
N P	6.31 c	9.40 c	12.64 b
N K	5.81 cdf	8.73 de	10.52 cd
N P K	7.15 ab	10.58 b	13.18 b
N S	5.47 ef	8.39 e	9.97 de
N Zn	5.67 def	8.70 de	10.25 d
N S Zn	6.97 b	10.100 b	13.13 b
N P K S Zn	7.56 a	12.08 a	14.81 a
N FYM	6.07 cd	9.27 cd	11.30 c
LSD	0.5452	0.6089	0.8245
CV (%)	5.19	4.83	4.22

Panicle length

The panicle length of Boro (BR11) rice shows some variation due to different treatment combinations under study (Figure 3). It varied from 17.88 to 21.46 cm where the lowest and highest values were found in control and NPKSZn treatments respectively. Addition of N alone slightly increased the panicle length over control. Addition of P further increased the length by more than one cm over N. The treatment NK slightly increased the panicle length over NP treatment, but a remarkable increase of about 1.4 cm over N alone. However, the addition of NPK together brought some benefit but it was not very remarkable. Addition S or Zn with N did not show any effect over N alone. But combined application of NSZn show some beneficial effect over N alone but not over NP, NK and NPK. Application of NPKSZn although showed the height length, it was close to NPK treatments.

Number of filled and unfilled grains per panicle

Counting the filled and unfilled grains per panicle a remarkable variation was observed between the treatments, as well as between the filled and unfilled grains (Table 3). The unfilled grains per panicle varied from 10.26 to 12.60 whereas the filled grains varied from 71.26 to 104.60 per panicle. The highest number of unfilled grains was found in control treatment, whereas the lowest number was in NZn treatment. But in case of filled grains, the lowest and highest numbers were found in control and NPKSZn treated plots respectively.

1000 grain weight

1000 grain weight of BR11 rice grown in permanent experimental plot also showed some variations due to different treatment combinations (Figure 4). It varied from 18.07 to 21.30 gm where the lowest and highest values were recorded in control and NPKSZn treated plots respectively. The 1000 grain weight of NK, NPK, NSZn and NFYM treatments were very closed to one another but lower than NPKSZn treatment. The 1000 grain weight due to NP, NS, NZn followed the above mentioned treatments.

Yield

Grain yield

Results on grain yield of BR11 rice grown after 30 years of intensive fertilization in permanent manurial experimental field have been presented in Figure 4.5. Due to 30 years of continuous fertilization, the yield of Boro/09 was influenced remarkably due to different treatment combinations. As expected, the yield of control plot (2.66 t ha^{-1}) was the lowest among the treatment combinations. The yield increased by 0.66 t ha^{-1} over control due to N alone. Application of P increased the yield slightly, however an amount of 1.55 t ha^{-1} over control and 0.39 t ha^{-1} over NP treatment was obtained due to combined application of N and K. The yields of NPK and NSZn treatments were closed to NK treatments. The highest yield of 4.49 t ha^{-1} was obtained due to NPKSZn treatment. The other treatments did not show encouraging effects. It is evident from the figure that after K containing treatments the yield of S containing treatment was also encouraging. This indicated that the soil of the experimental plot was deficient in N, K and S in addition to other macro and micro nutrients. Previous results indicated that K status of BAU farm soil severely decreased over the year and reached the value of 0.09 to 0.12 meq/100gm (Sharif 2009).

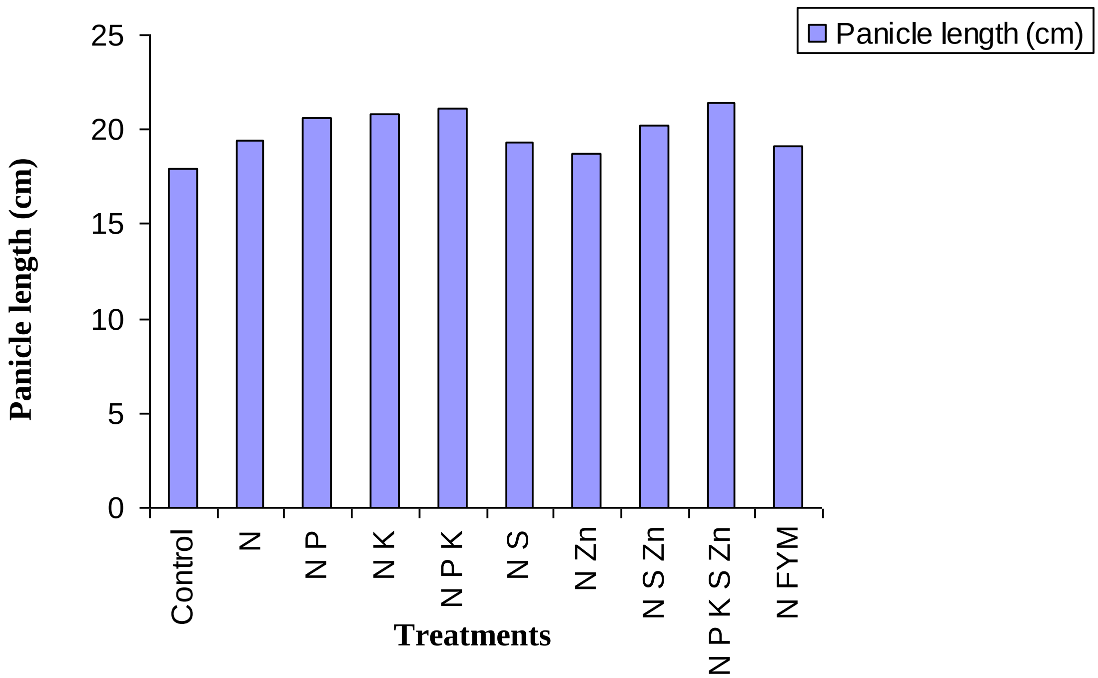

Figure 3
Panicle length (cm) of Boro rice at harvest.

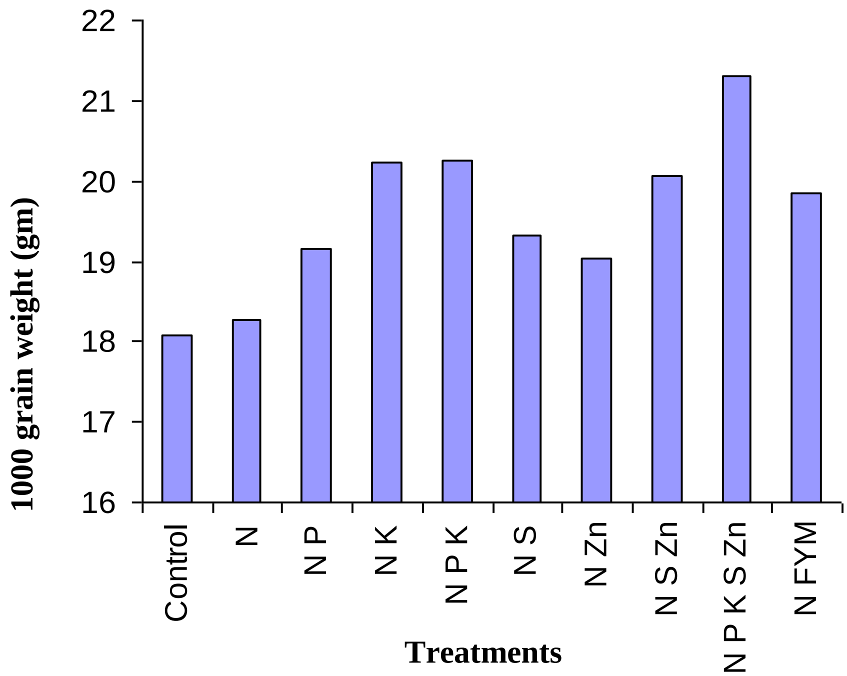

Figure 4
1000 grain weight (gm) of Boro rice at harvest.

Table 3
Effect of long-term fertilization on the unfilled and filled grains per panicle of BR11 rice.

Treatment	Number of unfilled grains	Number of filled grains
Control	12.60 a	71.26 d
N	11.13 bc	89.74 c
N P	12.20 ab	98.63 ab
N K	11.13 bc	98.56 ab
N P K	11.06 bc	102.35 ab
N S	10.40 c	98.73 ab
N Zn	10.26 c	96.80 abc
N S Zn	10.73 c	99.95 ab
N P K S Zn	11.40 bc	104.60 a
N FYM	11.20 bc	94.82 bc
LSD	1.126	7.840
CV (%)	5.86	5.78

The status of available S of BAU farm soil is also low to medium. In addition to this, long-term submergence of soil due to wet land rice cultivation kept the status of S very low because of soil reduction. Increasing water content during rice cultivation also dilutes the concentration. As a consequence, the status of these elements became low. This is probably the reasons for getting significant increase in yield due to renewed application of K and S along with N.

Straw yield

Like the grain yields, the straw yields of BR-11rice also varied remarkably due to different treatment combinations (Figure 5). The yield varied from 4.07 to 6.03 t ha^{-1} where the highest and lowest yields were obtained due to NPKSZn and control treatments respectively. In case of straw yield, the effects of N, K and S was also found prominent over others.

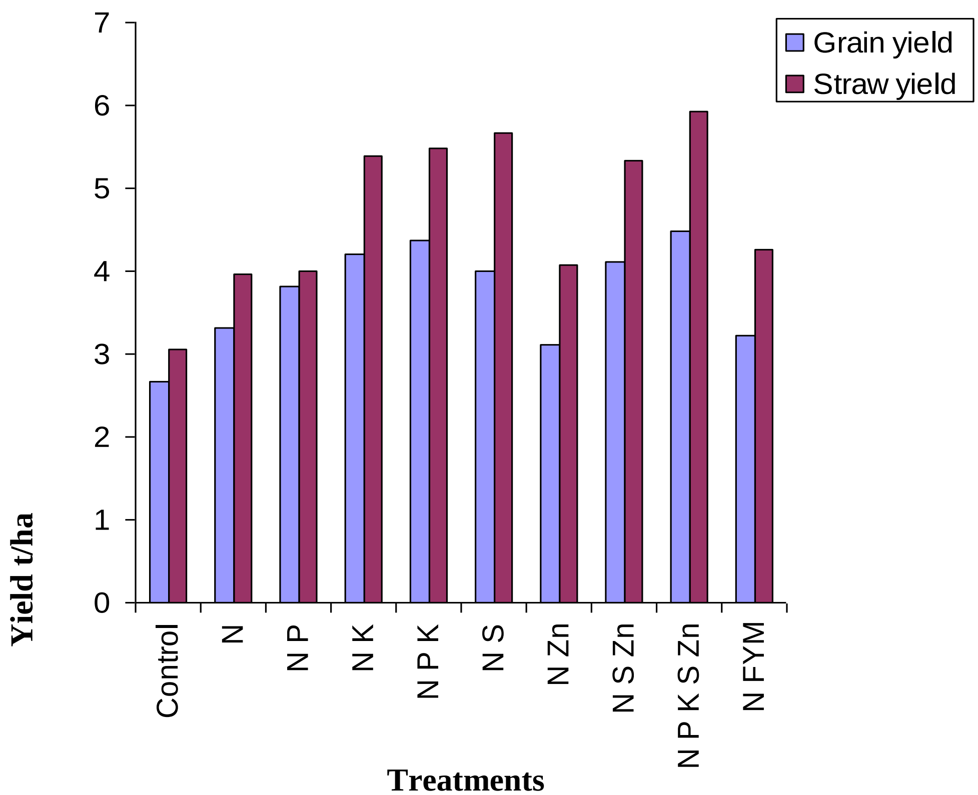

Figure 5
Effect of long-term fertilization on grain and straw yield of Boro rice.

Table 4
Effect of long-term fertilization on phosphorus content at different growth stages of BR11 rice.

Treatment	Phosphorus content (%)				
	45 DAT	60 DAT	75DAT	Straw	Grain
Control	0.117 ab	0.117 bc	0.128 ab	0.031 b	0.131 ab
N	0.108 ab	0.107 cd	0.133 ab	0.042 ab	0.148 a
N P	0.113 ab	0.119 bc	0.103 bcd	0.065 ab	0.125 ab
N K	0.130 a	0.140 b	0.121 abc	0.070 a	0.134 ab
N P K	0.119 ab	0.114 bcd	0.142 a	0.068 a	0.130 ab
N S	0.123 a	0.089 de	0.058 e	0.054 ab	0.105 b
N Zn	0.115 ab	0.075 e	0.073 de	0.050 ab	0.104 b
N S Zn	0.082 b	0.070 e	0.089 cde	0.058 ab	0.150 a
N P K S Zn	0.146 a	0.198 a	0.117 abc	0.065 ab	0.109 b
N FYM	0.115 ab	0.129 bc	0.133 ab	0.062 ab	0.109 b
LSD	0.03431	0.02426	0.02971	0.3020	0.02712
CV (%)	4.86	4.62	5.55	5.55	5.24

Nutrient content

Concentration of P in rice plant at different growth stages

Table 4 showed the concentration of P at different growth stages of rice plant grown in the permanent manurial experiment. It appears from the results that in general, in P treated plots the plant absorbed more P than others. The concentration was relatively low in plants treated with NS, NZn and NSZn treatments. It seems that the applied Zn have prevented in taking P due to formation of metal phosphate. However, when P was added with NKSZn the status increased slightly. The effect of farm yard manure was also found good. In general, the concentration of P in straw was the lowest in all treatment ranging from 0.031% to 0.094%. The concentration of P in grain was higher than straw.

Concentration of K in rice plant at different growth stages

Results of K concentration in plants grown in the permanent manorial experimental plot varied considerably at different growth stages (Table 5). In general, the concentration was high at 45 DAT ranging from 1.55% to 2.65%, which decreased to 1.42% to 2.02% at 60 DAT. It further decreased at 75 DAT ranging from 1.32% to 1.80%. At harvest stage the concentration did not changed remarkably over 75 DAT although an increase/decrease was noted in some treatments. The effect of different treatment was also variable, however, the plants treated with NK and NPK treatment contained higher K than others.

Concentration of S in rice plant at different growth stages

The concentrations of S in dry matter straw and grain have been presented in table 6. It appears from the results that the concentration of S was 0.033% to 0.280% at 45 DAT which decreased gradually with the passes of time and become lowest at harvest stage ranging from 0.023 to 0.050%. The concentration of S in grain was higher than straw ranging from 0.100% to 0.138%. Plants grown in S containing treatments contained higher amount of S than others.

Nutrient uptake

Total P uptake by grain and straw of Boro rice

The uptake of P varied considerably between the treatments ranging from 4.42 to 9.50 kg/ha. Highest and lowest values were obtained in control and NPK plots respectively table 7. In general, the uptake was found low compare to the findings obtained by other researchers.

During starting this present experiment the available soil P content was 8.0 ppm. This status was low compare to the critical limit (10 ppm) as suggested by the BARC (2005). The relatively low P content in plant as well as total uptake was possibly due to the P deficiency in soils. Treatments containing P showed relatively higher value than others although some minor variations existed.

Table 5
Effect of long-term fertilization on Potassium content at different growth stages of BR11 rice.

Treatment	Potassium content (%)				
	45 DAT	60 DAT	75DAT	Straw	Grain
Control	1.550 e	1.500 c	1.320 b	0.700 e	0.117 c
N	1.650 de	1.420 c	1.570 a	0.970 d	0.120 c
N P	1.900 cd	1.500 c	1.600 a	1.200 c	0.170 ab
N K	2.600 a	2.353 a	1.800 a	1.920 a	0.190 a
N P K	2.150 bc	1.950 b	1.600 a	1.900 a	0.190 a
N S	2.250 b	1.950 b	1.750 a	1.500 b	0.180 a
N Zn	2.150 bc	1.900 b	1.600 a	1.520 b	0.150 b
N S Zn	2.200 b	1.600 c	1.600 a	1.550 b	0.100 c
N P K S Zn	2.650 a	1.800 b	1.700 a	1.900 a	0.190 a
N FYM	2.000 bc	1.900 b	1.700 a	1.600 b	0.120 c
LSD	0.2544	0.1879	0.2101	0.1715	0.02486
CV (%)	7.02	10.06	7.53	6.89	4.56

Table 6
Effect of long-term fertilization on sulphur content at different growth stages of BR11 rice.

Treatment	Sulphur content (%)				
	45 DAT	60 DAT	75DAT	Straw	Grain
Control	0.150 e	0.022 f	0.050 e	0.025 b	0.117 ab
N	0.280 a	0.170 c	0.130 cd	0.030 ab	0.112 ab
N P	0.209 c	0.107 e	0.890 a	0.033 ab	0.138 a
N K	0.244 b	0.248 a	0.192 b	0.036 ab	0.114 ab
N P K	0.180 d	0.141 d	0.187 b	0.048 ab	0.100 b
N S	0.246 b	0.212 b	0.113 d	0.045 ab	0.114 ab
N Zn	0.265 ab	0.132 de	0.148 c	0.023 b	0.105 b
N S Zn	0.245 b	0.121 de	0.119 d	0.046 ab	0.104 b
N P K S Zn	0.260 ab	0.207 b	0.108 d	0.034 ab	0.112 ab
N FYM	0.033 f	0.016 f	0.156 c	0.057 a	0.120 ab
LSD	0.02544	0.02602	0.02630	0.02607	0.02663
CV (%)	5.99	6.48	5.54	5.65	4.26

Table 7
Effect of long-term fertilization on phosphorus uptake by grain and straw of BR11 rice.

Treatment	Phosphorus uptake (kg ha^{-1})		
	Straw	Grain	Total
Control	0.94 f	3.48 e	4.42 f
N	1.66e	4.91 c	6.57 d
N P	2.60 c	4.77 c	7.37 c
N K	3.77 a	6.30 a	9.41 a
N P K	3.73 a	5.77 b	9.50 a
N S	3.06 b	4.20 d	7.26 c
N Zn	2.03 d	3.23 e	5.26 e
N S Zn	3.09 b	4.71 c	7.80 c
N P K S Zn	3.85 a	4.88 c	8.73 b
N FYM	2.97 b	3.49 e	6.13 d
LSD	0.3639	0.5001	0.5397
CV (%)	7.69	6.36	4.35

Total K uptake by grain and straw of Boro rice

Considering the uptake of K, a strong variation ranging from 24.61 to 121.2 kg/ha was found in the present study after 30 years of continuous fertilization (Table 8). In K treated plots, the uptake varied from 111.5 to 121.2 kg/ha whereas in plots, containing S the uptake varied from 86.7 to 92.1 kg/ha which was again higher than the uptake from plots where either K or S was not applied. This indicated that S has some positive effect on the uptake of K by plants. Both in control as well as in the K treated plots the status of soil K was low. This might be the main reason for the lower values of K uptake.

Total S uptake by grain and straw of Boro rice

The uptake of S was also considerably low ranging from 3.87 to 7.2 kg/ha, where the lowest and highest values were in control and NPKSZn treated plots respectively (Table 9). The uptake of S due to the treatments NK, NPK, NS, NSZn and NPKSZn was high ranging from 6.73 to 7.22 kg/ha, where as in other plots it varied from 3.87 to 6.28 kg/ha.

Table 8
Effect of long-term fertilization on potassium uptake by grain and straw of BR11 rice.

Treatment	Potassium uptake (kg ha^{-1})		
	Straw	Grain	Total
Control	21.42 h	3.19 g	24.61 g
N	38.50 g	3.98 f	42.48 f
N P	48.00 f	6.49 d	54.49 e
N K	103.48 b	7.99 b	111.47 b
N P K	104.31 b	8.30 ab	112.61 b
N S	84.90 c	7.20 c	92.10 c
N Zn	61.86 e	4.66 e	66.52 d
N S Zn	82.61 c	4.12 f	86.73 c
N P K S Zn	112.67 a	8.53 a	121.20 a
N FYM	68.16 d	3.86 f	72.02 d
LSD	5.191	0.3516	6.129
CV (%)	4.17	3.49	4.56

Table 9
Effect of long-term fertilization on sulphur uptake by grain and straw of BR11 rice.

Treatment	Sulphur uptake (kg ha^{-1})		
	Straw	Grain	Total
Control	0.760 g	3.110 g	3.870 f
N	1.220 e	3.710 f	4.930 e
N P	1.320 e	4.100 df	5.420 d
N K	1.940 d	4.790 ab	6.730 b
N P K	2.630 a	4.370 cd	7.000 ab
N S	2.540 ab	4.560 bc	7.100 ab
N Zn	0.930 f	3.260 g	4.190 f
N S Zn	2.450 b	4.260 cd	6.730 b
N P K S Zn	2.200 c	5.020 a	7.220 a
N FYM	2.420 b	3.860 ef	6.280 c
LSD	0.1627	0.3388	0.3986
CV (%)	5.08	4.81	3.89

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