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Effect of potassium application on crop productivity in Boro rice production

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ABSTRACT

An experiment was conducted on the research farm of Bangladesh Institute of Nuclear Agriculture, Mymensingh during 2007 to investigate the effect of different levels of K application on Boro rice production in Old Brahmaputra Flood Plain Soil. The soil type was Non-Calcareous Dark Grey Floodplain. The experiment was laid out in a randomized complete block design with three replications. The treatment combinations were T_1, (absolute control), T_2 (full dose of NPSZnB), T_3 (50% of estimated K + full dose of NPSZnB), T_4 (75% of estimated K + full dose of NPSZnB), T_5 (100% of estimated K + full dose of NPSZnB) and T_6 (K equal to estimated apparent balance + full dose of NPSZnB). The growth and yield contributing characters were significantly influenced by the treatments. For Boro rice (var. Binadhan 5), the yield attributes and the grain and straw yields responded significantly due to the treatments. The grain and straw yields of Boro rice ranged from 2.15 to 6.45 t ha^{-1} and 2. 80 to 8.06 t ha-1, respectively. The highest grain yield of 6.45 t ha^{-1} was obtained in treatment T_5 (100% of estimated K + full dose of NPSZnB). A minimum replenishment of K from the soil reserve was observed. Economics of fertilizer uses for Boro rice cropping showed that among the treatments, T_5gave the highest benefit cost ratio 7.58. The results indicated that in order to obtain sustainably higher crop yield under intensive rice cultivation, the addition of potash fertilizer is necessary.

INTRODUCTION

The cropping patterns of Bangladesh are mainly rice (*Oryza sativa* L.) based because rice is grown in about 75% of the total cropped area and more than 80% of the total irrigated area (Anonymous, 2016a). The country achieves an autarky to meet up the rice demand for its 169.04 million peoples from 11.55 million hectares of cultivated gross area (Kabir et al., 2020; Nasim et al., 2021). Boro rice covers an area of 4.77 million hectares with a production of 19.88 million tons (BBS, 2021). The average yield of rice in Bangladesh is 3.86 t ha^{-1} (BBS, 2021) and which is much lower than world average. Although, rice is the staple food in Bangladesh as it constitutes 97% of the total food grain production (BBS, 2021). It is the agricultural commodity with the third-highest worldwide production (BBS, 2018).

Potassium (K) is important to find its economic use in a poor country like Bangladesh by identifying the soils as well as crops most responsive to K application. It is also necessary to determine the need for supplementary application of K for different crops grown in soils of different levels of potassium. Potassium is often described as the ‘Quality element’ for crop production (Haque and Rahman, 2004). Proper fertilization effectively improves quality and yield of crops, reduces cost and increases farmers’ income. On the contrary, improper fertilization not only reduces crop yield and quality, but also increases cost, reduces fertilizer use efficiency and creates adverse effects on the soil environment. Potassium is considered to be second in uptake by most of the agricultural crop. Unfortunately in our country while considering different aspects of K nutrition to crops emphasis has been laid on inherent supply of K from soil to plant for a long time. On the

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other hand, there exists a gap between annual potassium removal by the crops from the soil and potassium addition through external sources. It would be very optimistic from our part to expect that this deficit of K will be balanced from the native and organic sources at the right time of physiological need of the crop. If we do not stress the adequate use of potassium in crop production this gap will widen further with increased target of food production.

Potash has great importance in crop growth and development and dressings of potassium can alleviate the sterility problem in rice. As evidenced by research findings, a large percentage of sterile or unfilled spikelets are caused by poor pollen viability and this retards carbohydrate translocation due to potassium deficiency (Dobermann and Fairhurst, 2000).

Potassium helps to control the severity of plant diseases and increase the plant resistance to drought and other stresses. It performs many functions in plant such as promoting growth and increasing yield, increasing resistance to pests, promoting root growth, regulating water utilization by plant, strengthening plant tissues and preventing lodging. Lodging of rice plant increases sterility during flowering, which causes the yield reduction in rice. Potassium increases strength of rice stalk, and thus prevents lodging and reduces sterility.

A number of factors influence rice production and obviously nutrients play a great role. But intensive crop culture with high cropping intensity initiates problems in relation to supplying nutrients from soil. It has been found that for every 1000kg of rice production 26-32 K_2O is removed from soil (Takahashi, 1996, De Datta and Morris, 1983). Potassium removal is higher in modem verities than in traditional ones (Uexkull, 1984). To avoid continuous removal of the K reserve of the soil; fertilizer application rates should not be based only on soil test and crop response but also on the amount removed by the harvested portion of the crop. Hence an experiment was conducted on typically K deficient soil with different levels of K fertilizers along with other full doses of fertilizers for generating information and to formulate site specific K requirement at boro rice production.

Considering the above points, the present study was undertaken with the following objectives:

i. To study the changes of different forms of K with time in Old Brahmaputra Flood Plain soil,
ii. To study the effect of applied K on yield and yield contributing characters in the boro- rice production and
iii. To determine the effect of K fertilizer on nutrient uptake by boro rice (var. BINAdhan 5)

MATERIALS AND METHODS

Site and soil

The experiments were conducted at BINA farm, Mymensingh, Bangladesh.

Morphological description of the soil

Location	BINA farm, Mymensingh
Agro Ecological Zone	Old Brahmaputra Flood plain
Land type	Medium high land
General soil type	Non Calcareous Dark Grey
Parent materials	Old Brahmaputra Alluvium
Drainage	Well drained
Flood level	Above flood level
Soil series	Sonatala

Physical and chemical properties of the initial soil sample

Physical characteristics	
Sand	41.35
Silt	48.25
Clay	10.40
Textural class	Silt loam
Chemical characteristics	
pH	6.2
Organic matter (%)	1.56
Total N (%)	0.09
Available P (ppm)	33.12
Available S (ppm)	6.29
Available Zn (ppm)	0.82
Available B (ppm)	0.28
Exchangeable K (ppm)	13.4
Exchangeable Ca (meq%)	1.85
Exchangeable Mg (meq%)	0.72

Climate

The experimental area belongs to sub-tropical climate and is characterized by high temperature accomplished by moderately high rainfall during kharif season (April to September) and low temperature in rabi season temperature is generally low and there is plenty of sunshine. The atmospheric temperature tends to increase from February as the season proceeds towards kharif.

Treatments

The experiment was comprised six treatments including absolute control of (Boro var. BINAdhan 5). The fertilizer treatments used in the experiment were based on soil analysis. The details of the treatments used in boro rice production in these experiments are given in 1. The sources of N, P, K, S and Zn nutrients were Urea, TSP, MOP, Gypsum and Zinc oxide, respectively.

Table 1: Details of nutrient (kg ha^{-1}) for Boro rice production

Treatment	Boro (var. BINA dhan 5)					
	N	P	K	S	Zn	B
T1 (Absolute control)	0	0	0	0	0	0
T2 (Without K + Full dose of NPSZnB)	140	20	0	20	3	2
T3 (50% K+ Full dose of NPSZdB)	140	20	40	20	3	2
T4 (75% K + Full dose of NPSZnB)	140	20	60	20	3	2
TS (100% K + Full dose of NPSZnB)	140	20	80	20	3	2
T6 (K equal to estimated apparent balance + Full dose of NPSZnB)	140	20	93	20	3	2

Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three replications of each treatment. Each replication represented a block. Each block was divided into six unit plots for the selected cropping sequence. There were 18 (6×3) unit plots. The unit plot size was 5m × 4m. The spacing between blocks was 1 m and between plots was 0.5m. The treatments were randomly distributed to unit plots in each block. The layout of the experiment was done in accordance with the statistical design and kept undisturbed for Boro rice (var. Binadhan 5).

Crops

The experiment was on Boro rice (var. Binadhan 5) as a test crop. The average yield potential of this rice variety is 5.5 -6.5 t ha^{-1}. The maximum grain yield of this variety under proper cultural practices is 8t ha^{-1}. It requires 150-155 days to complete its life cycle (from seed sowing to harvest).

Land preparation, seedling raising and transplanting

Land preparation was started on 1st February. Then the land was made saturated with irrigation water and prepared by successive ploughing, cross ploughing and laddering. All kinds of weeds, stubbles and crop residues were removed from the field before final ploughing and leveling.

For raising the seedling a previously prepared puddle land was selected for the seedling nursery. The seeds were broadcast on the prepared seedling nursery. Seeds were sown as uniformly as possible. Forty-day old seedlings were transplanted in the experimental plots on 08th February. A distance of 25 cm from row to row and 15cm from plant to plant was maintained. Three seedlings were used in each hill.

Fertilizer application

The full dose of each of triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc oxide, boric oxide and 1/3 of urea were applied in boro rice at the time of final land preparation. The rest of urea was applied in two equal split, one after 30 days of transplanting i.e. at maximum tillering stage and second installment after 60 days of transplanting i.e. at panicle initiation stage or booting stage of crop.

Intercultural operations

Intercultural operations (Irrigation, Weeding, Insect and pest control, Harvesting and threshing) were done for ensuring and maintaining the normal growth of the crop.

Collection and preparation of soil samples

Soils were collection at a depth of 0-15 cm from 10 spots of land. The samples were air dried, ground and sieved through 2 mm (8mesh) sieve. The composite sample was stored in a clean plastic container for physical and chemical analysis. Soils sampling was done before ploughing the lands.

Soil analysis

The initial soil sample was analyzed for soil texture, pH, organic matter, total N and available P, K, S and Zn content following the USDA system 1951.

Plant Samples Analysis

Plant samples collected from the field experiment were analyzed for N, P, K and S contents according to the protocol described by (REF). Grain and straw samples were dried in an oven at about 65°C for 48 hours and then ground in a grinding mill to pass through a 20 mesh sieve. The ground plant material (grain and straw) were stored in small paper bags and placed in a desiccator. The methods followed in plant analyses (grain and straw) were as follows.

Statistical analysis

The analysis of variance for every crop parameters and also for the nutrient content and nutrient uptake by the grain and straw were done following the principles of F-statistics and the mean results in case of significant F-value adjusted by the Duncan's Multiple Range Test (DMRT).

RESULT AND DISCUSSION

Effect of K fertilizer on growth and yield contributing characters

Plant height

Among the yield contributing characters, plant height was significantly influenced by the different treatments. Plant height increased significantly due to different treatments compared to control treatment (Table 2). Plant heights ranged from 86.9 to 110.0 cm. The highest plant (110.0) was attained in treatment T_6 (K apparent balanced). The shortest plant (86.9) was observed in treatment T_1, (absolute control). Plant height obtained in treatment T_6 was higher than that of other treatments. Treatment T_6 was statistically identical with the treatment T_5. The results indicated that addition of K nutrient showed significant effect on plant height. Biswas et al. (2001) found that plant height varied significantly due to K rates.

Tillers hill^{-1}

The number of tillers hill-1 was also significantly influenced by the different treatments. The number of tillers hill^{-1} ranged from 8.4 to 12.8 (Table 2). The highest number of tillers hill^{-1} (12.8) was obtained in the treatment T_5. The lowest number of tillers hill^{-1} (8.4) was recorded in treatment T1. Further treatments T_4 and T_3 produced statistically identical tillers hill^{-1}. The result suggests application of K had significant effect on the number of tillers hill-^{1}. Sarker et al. (1995) also observed that application of potassium increased the number of tillers hill^{-1}. Mondal et al. (1987) also reported that increasing rates of K_2O from 40 to 160 kg ha-^{1} increased the number of tillers hill^{-1}.

Panicle length

Like plant height and tillers hill"', panicle length were also significantly influenced by the different treatments (Table 2). Panicle length ranged from 22.4 to 25.9 cm. The tallest panicle length (25.9 cm) was observed in the treatment T_4 which was statistically identical with T_3 and T_2. The shortest panicle length (22.4 cm) was observed in treatment T_1.

Grains panicle^{-1}

The number of grains panicle^{-1} was significantly affected due to application of K fertilizer. The number of grains panicle-1 ranged from 96 to 151 (Table 2). The highest number of grains panicle^{-1} 151 was found in treatment T_6 which was statistically different with all other treatments.

On the other hand, the lowest number of grains $panicle^{-1}$ 96 was recorded in treatment T_1. Mitra et al. (2001) reported that the application of K fertilizer significantly increased number of grains $panicle^{-1}$. Talukder (1992) also found that application of K_2O up to 60 kg ha-1 increased the grains $panicle^{-1}$.

1000-grain weight

1000-grain weight was also influenced by different treatments used in the experiment (Table 2). Thousand-grain weight ranged from 23.30 to 26.05 g. The highest 1000-grain weight was observed in the treatment T_5 which was statistically identical with treatments T_6, T_4 and T_3. The lowest 1000 grain weight was observed in treatment T_2 which was statistically identical with treatment T_1. Mitra et al. (2001) reported that the application of K increased 1000-grain weight of rice.

Effect of different treatments on grain and straw yields

Grain yield

Grain yield of boro rice (var. Binadhan 5) responded significantly due to application of K fertilizer (Table 3, Figures 1 and 2). Different treatment combinations also gave significantly higher grain yield over the treatment T_1. The grain yield of boro rice varied from 2.15 to 6.45 t ha^{-1}. The treatment T_5 (full dose of NPSZnB and 100% K) produced the highest grain yield of 6.45 t ha-1 which was 200% increase over control and statistically similar with treatments T_6, T_4 and T_3. The lowest grain yield (2.15 t ha^{-1}) was obtained in the treatment T_1 (absolute control) which was statistically different from all other treatments. The second highest grain yield was observed in treatment T_6 (K apparent balance) which was statistically similar to treatment T_4 (75%K) and treatment T_3. In producing grain yield the treatment may be ranked in order of $T_5 > T_6 > T_4 > T_3 > T_2 > T_1$. The percent increase in grain yield over control ranged from 156-200%. However, the highest percent increase in grain yield 200% was recorded in treatment T_5. Singh and Singh (2000) was reported the highest grain yield of rice was obtained at 90kg K_2O ha^{-1} in all the years.

Straw yield

Like grain yield, the straw yield of boro rice responded significantly due to application of K (Table 3 and Figure 1). The straw yield varied from 2.80 to 8.06 t ha^{-1}. The highest straw yield (8.06 t ha^{-1}) was recorded in treatment T6 (K apparent balance). The lowest straw yield (2.80 t ha^{-1}) was recorded in the treatment T_1 (absolute control). In producing straw yield, the treatments may be ranked in order of $T_6 > T_5 > T_4 > T_3 > T_2 > T_1$.

The percent increase in straw yield over control also followed more or less same trend as observed in case of grain yield. The percent increase in straw yield over control ranged from 146 to 188%. However, the highest percent increase in straw yield, 188% was recorded in treatment T_6.

This result indicated that there was significant contribution of K along with the full doses of NPSZnB to straw yield of boro rice and when the rate of K was increased the straw yield was also increased at certain level. Singh et al. (1999) found that application of potassium enhanced the straw production. Singh and Singh (2000) was reported the highest straw yield of rice was obtained at 90 kg K_2O ha^{-1} in all the years.

Effect of K on nutrient content and uptake by grain and straw

Nitrogen content

The nitrogen content in grain and straw of Binadhan 5 was influenced by K application along with full doses of NPSZnB. The grain N content varied from 0.78 to 1.13 (Table 4). The highest grain N content was observed in treatment T_4 and T_5 (1.13%) which was statistically identical with T_3 (1.12%) and T_6 (1.10%). The lowest grain N content was observed in the treatment T_1 (0.78%). In straw, N content varied from 0.387% to 0.480%. The highest N content in straw was recorded in treatment T_3.

Table 2: Effect of K on the yield components of boro rice

Treatments	Plant height (cm)	Tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	1000-grain weight (g)
T_1	86.9d	8.4c	22.4d	96f	23.57b
T_2	107.9b	11.Sa	25.2ab	102e	23.30b
T_3	108.7b	11.9ab	25.Sab	128d	25.10a
T_4	106.8c	12.4ab	25.9a	136c	25.65a
T_5	109.9a	12.8a	24.6b	140b	26.0Sa
T_6	110.0a	11.8b	23.4c	151a	25.80a
CV (%)	2.47	4.46	2.32	2.51	3.07
SE (f)	0.48	0.30	0.33	1.10	0.444

In a column, figure (s) followed by the same letter (s) do not differ significantly at 5% level by DMRT; SE (±) = Standard Error of means

Table 3: Effect of different K on the grain and straw yields of Boro rice

Treatments	Grain Yield (t ha^{-1})	Yield increase (%) Over control	Straw Yield (t ha^{-1})	Yield increase (%) Over control
T1	2.15c	-	2.80f	-
T2	5.50b	156	6.88e	146
T3	5.95a	177	7.30d	161
T4	6.15a	186	7.40c	164
TS	6.45a	200	7.75b	177
T6	6.20a	188	8.06a	188
CV(%)	4.46	-	2.67	-
SE (f)	0.140	-	0.025	-

In a column, figure (s) followed by the same letter (s) do not differ significantly at 5% level by DMRT, SE (±) = Standard Error of means (0.480%) which was statistically dissimilar with other treatment. The lowest N content was found in the treatment T_1 (absolute control).

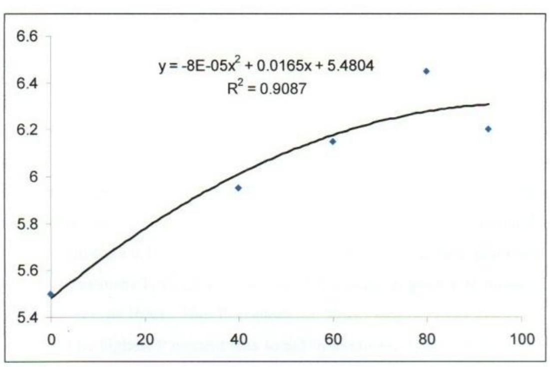

Figure 1: Response of boro rice to applied K

Nitrogen uptake

Like nitrogen content, uptake by grain and straw of boro rice were also influenced due to different treatments (Table 4). The ranges of N uptakeby grain and straw were 16.7 to 73.1 kg ha^{-1} and 10.9 to 37.3 kg ha^{-1}, respectively. The highest N uptake by grain was recorded in treatment T_5 (73.1 kg ha^{-1}) and the lowest N uptake by grain was found in treatment T_1, (16.7 kg ha^{-1}). The maximum N uptake by straw (37.3 kg ha^{-1}) was recorded in treatment T_5 which was statistically similar with treatments T_6 (35.5 kg ha^{-1}). The minimum N uptake by straw was found in treatment T_1, (10.9 kg ha^{-1}). The results observed that the N uptake was higher in grain than that of straw.

The ranges of total N uptake both by grain and straw were 27.5 to 1 l 0.4 kg ha^{-1}. The highest total N uptake (110.4 kg ha^{-1}) was recorded in treatment T_5. The lowest N uptake was observed in treatment T_1. Mitra et al. (2001) reported that uptake of N increased significantly with increase in levels of K for rice. A linear relationship between grain yield and N uptake was obtained where grain yield increased with increasing uptake of N (Figure 3).

Phosphorus content

Results shown in Table 5 indicated that phosphorus content in grain and straw were significantly influenced due to different treatments. P content in grain varied from 0.16 to 0.23%. The highest P content 0.23% in grain was found in treatment T_3 (0.23%). The lowest P content in grain was found in treatment T_1 (0.16%). The P content in straw ranged from 0.093 to 0.137%. The highest P content was found in treatment T_5 (0.137%) which was statistically identical with treatments T_3 (0.130%) and T_6 (0.120%). The lowest P content was recorded in treatment T_1, (0.093%) which was statistically different from all other treatments.

Phosphorus uptake

Phosphorus uptake by grain and straw were significantly influenced by the different treatments (Table 5). Phosphorus uptake by grain ranged from 4.6 to 14.1 kg ha^{-1}.The highest P uptake (14.1 kg ha^{-1}) was recorded in treatment T_5. The lowest P uptake by grain was obtained in treatment T_1 (4.6 kg ha^{-1}).In straw, there was no different in respect of P uptake within different treatments except treatment T_1. The total P uptake by grain and straw varied from 6.2 to 24.1 kg ha^{-1} due to treatments. The highest total P uptake (24.1 kg ha^{-1}) was found in treatment T_5. The lowest total P uptake (6.6 kg ha^{-1}) was obtained in treatment T_1. Mitra et al. (2001) reported that the uptake of P increased significantly with increase in levels of K for rice. A linear relationship between grain yield and P uptake was obtained. Figure 3 indicates that grain yield increased with increasing uptake of P.

Potassium content

Potassium in grain and straw were significantly affected by different treatments. The K content in grain and straw varied from 0.220 to 0.253% and 1.23 to 1.67%, respectively (Table 6). The highest K content in grain were recorded in treatments T_5 (0.250) and T_4 (0.250%). The lowest K content (0.220%) was obtained in treatment T_1 (absolute). In straw, the highest K content (1.67%) was found in treatment T_6 (K apparent balance + full dose of NPSZnB), which was statistically identical with all other treatments except T_1. The lowest K content in straw (1.23%) was observed in treatment T_1 (absolute control). Gill and Kamparath (1990) reported that K application increased K content in rice. Saleque et al. (1998) reported that K application increased K content in the straw.

Table 4: Effect of K on the nitrogen content and uptake by grain and straw of Boro rice

Treatments	N content (%)		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
T_1	0.78b	0.387cd	16.7e	10.9e	27.5e
T_2	1.09a	0.450b	60.3d	25.7d	86.0d
T_3	1.12a	0.480a	66.6c	28.8c	95.4c
T_4	1.13a	0.440b	69.5b	33.6b	103.1b
T_5	1.13a	0.373d	73.1a	37.3a	110.4a
T_6	1.10a	0.393c	68.2bc	35.5ab	103.7b
CV (%)	4.12	5.13	1.68	5.39	2.07
SE (±)	0.026	0.006	0.57	0.89	1.05

In a column, figure (s) followed by the same letter (s) do not differ significantly at 5% level by DMRT, SE (±) = Standard Error of means

Table 5: Effect of K on the phosphorus content and uptake by grain and straw of boro rice

Treatments	P content (%)		P uptake (kg ha^{-1})		Total P uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
	0.16d	0.093d	3.6c	2.6d	6.2c
T_2	0.19c	0.113bc	10.5b	7.8c	18.2b
T_3	0.23a	0.130ab	13.9a	9.5ab	23.4a
T_4	0.23a	0.110cd	14.1a	8.1bc	22.3a
T_5	0.21b	0.137a	13.5a	10.6a	24.1a
T_6	0.21b	0.120abc	13.4a	9.7ab	23.1a
CV (%)	8.13	10.05	8.60	8.77	4.88
SE (f)	0.006	0.006	0.57	0.50	0.55

In a column, figure (s) followed by the same letter (s) do not differ significantly at 5% level by DMRT;
SE (±) = Standard Error of means

Potassium uptake

Data in Table 6 indicated that the K uptake of grain and straw was also significantly influenced by the different treatments. The K uptake by grain varied for 4.7 to 16.1 kg ha^{-1}. The highest K uptake by grain (161 kg ha^{-1}) was recorded in the treatment T_5 (100% of estimated K + full dose of NPSZnB), which was statistically identical with all other treatments (except T_1). The lowest K uptake by grain (4.7 kg ha^{-1}) was observed in treatment T_1 (absolute control). In case of straw, the K uptake ranged from 34.5 to 134.3 kg ha^{-1}. The highest K uptake by straw (134.3 kg ha^{-1}) was found in treatment T_6 which was statistically similar with treatments T_5 (124.0 kg ha^{-1}) and T_4 (120.9 kg ha^{-1}). The lowest K uptake by straw (34.5 kg ha^{-1}) was obtained in treatment T, (absolute control). Roy and Kumar (1995) found a significant increase in K uptake with rate of K application. Mitra et al. (2001) reported that the level of K increased significantly with increase in level of K for rice. A linear relationship between grain yield and K uptake was obtained. Figure 4 indicates that grain yield increased with increasing uptake of K.

Sulphur content

Data in Table 7 revealed that S content of both grain and straw differed significantly due to different treatments. The S content in grain ranged from 0.10% to 0.12%. The highest S content in grain were obtained in treatments T_5 and T_6 which were statistically similar with treatments T_2 (0.11 %), T_3 (0.11 %) and T_4 (0.11 %). The lowest S content in grain (0.10%) was found in treatment T_1. The S content in straw was ranged from 0.07-0.09%. However, the highest and lowest S content were recorded in treatment $T_6$and T_1 respectively.

Sulphur uptake

The results indicated that the S uptake by grain straw was significantly influenced by the different treatments (Table 7). The highest S uptake by grain (7.7 kg ha^{-1}) was observed in treatment T_5 which was statistically similar with treatments T_4 (6.8 kg ha^{-1}) and T6 (7.4 kg ha^{-1}). The lowest S uptake by grain (2.2 kg ha^{-1}) was obtained in treatment T^1. On the other hand, the highest S uptake by straw (7.5 kg ha^{-1}) was found in treatment T_5 which was statistically similar with other treatments except T_1. The total S uptake by grain and straw varied from 4.2 to 15.2 kg ha^{-1}. The highest total S uptake 15.2 kg ha_{-1} was recorded in treatment T_5 which were statistically identical with treatments T_4 (13.2 kg ha^{-1}) and T_6 (14.7%). The lowest total S uptake (4.2 kg ha^{-1}) was found in treatment T_1. Mitra et al. (2001) reported that the uptake of S increased significantly with increase in levels of K for rice. A linear relationship between grain yield and S uptake was obtained. Figure 5 indicates that grain yield increased with increasing uptake of S.

Status of different forms of initial and post-harvest soil potassium

The status of water soluble, exchangeable, non-exchangeable and total potassium of initial soil was

2.80 ppm, 13.4 ppm, 18.32 ppm and 2.10%, respectively. The water soluble K of post-harvest soil varied from 1.50 to 2.55 ppm. The highest water soluble K was found in T_6 (2.55 ppm) and the lowest was in treatment T_1, (1.50 ppm). The exchangeable and non-exchangeable K of post-harvest soil varied from 10.40 to 13.10 ppm and 15.80 to 18.15 ppm over the treatments. The highest non-exchangeable K was found in treatment T_6 (18.15 ppm) and the lowest was in treatment T1 (15.80 ppm). Again the highest total K were found in treatments T_5 (1.96 ppm) and T_6 (1.96 ppm). The lowest total K was observed in treatment T_1, (1.54 ppm).

Table 6: Effect of K on the potassium content and uptake by grain and straw of Boro rice

Treatments	K content (%)		K uptake (kg ha^{-1})		Total K uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
T1	0.22	1.23b	4.7b	34.Sc	39.3d
T2	0.20	1.40ab	13.2a	96.3b	109.Sc
T3	0.24	1.60ab	14.Sa	104.6b	119.1 be
T_4	0.25	1.63a	15.4a	120.9ab	136.2abc
TS	0.25	1.43ab	16.1 a	124.Oab	140.1 ab
T6	0.25	1.67a	15.7a	134.3a	150.Oa
CV (%)	10.61	9.08	11.68	8.52	13.00
SE (f)	0.018/NS	0.113	0.90	6.59	8.69

In a column, figure (s) followed by the same letter (s) do not differ significantly at 5% level by DMRT, SE (±) = Standard Error of means

Table 7: Effect of K on the sulphur content and uptake by grain and straw of boro rice

Treatments	S content (%)		S uptake (kg ha^{-1})		Total S uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
T_1	0.10b	0.07b	2.2d	2.1b	4.2d
T_2	0.1lab	0.09a	5.9c	6.Oa	11.8c
T_3	0.11 ab	0.07a	6.7bc	6.3a	13.1 be
T_4	0.11 ab	0.09ab	6.8abc	6.9a	13.7ab
T_5	0.12a	0.09b	7.7a	7.5a	15.2a
T_6	0.12a	0.09b	7.4ab	7.3a	14.7ab
CV(%)	7.49	10.24	8.24	9.13	7.92
SE (t)	0.006	0.006	0.29	0.46	0.55

In a column, figure (s) followed by the same letter (s) do not differ significantly at 5% level by DMRT, SE (±) = Standard Error of means

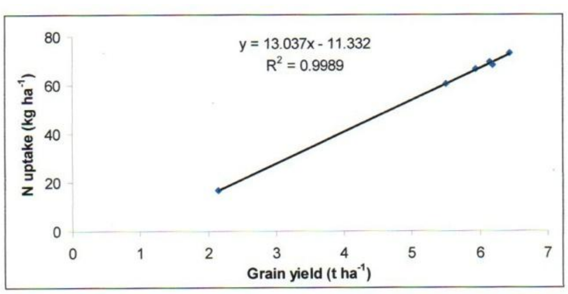

Figure 2: Relationship between grain yield and N uptake of boro rice

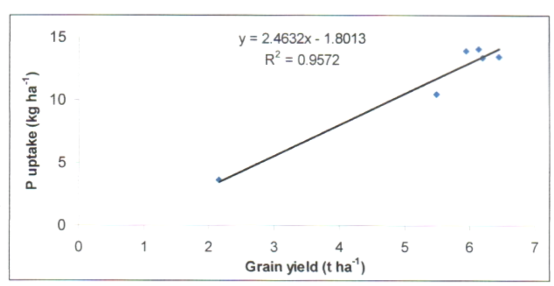

Figure 3: Relationship between grain yield and P uptake of boro rice

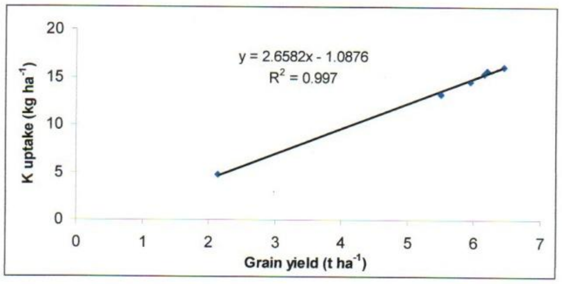

Figure 4: Relationship between grain yield and K uptake of boro rice

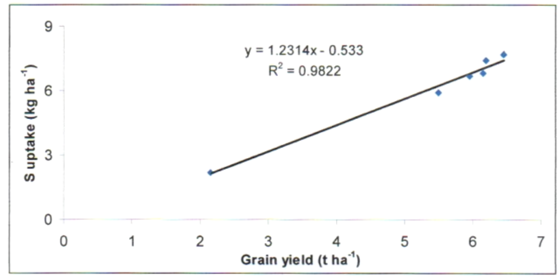

Figure 5: Relationship between grain yield and S uptake of boro rice

Table 8: Status of different forms of initial and post harvest soil potassium

Treatment	Water soluble K (ppm)	Exchangeable K (ppm)	Non-exchangeable (1.4N H_2SO4 extractable) K (ppm)	Total K (%)
Initial soil	2.80	13.4	18.32	2.10
Post harvest soil				
T,	1.50	10.40	15.80 I	1.54
T2	1.55	11.04	16.50	1.68
T3	2.25	12.10	17.40	1.68
T4	2.45	12.50	17.80	1.82
T5	2.50	13.00	18.10	1.96
T_6	2.55	13.10	18.15	1.96

CONCLUSION

The total N, P, K and S uptake of boro rice significantly influenced by the different treatments. The total N, P, K and S uptake varied from 27.5 to 110.4, 6.2 to 24.1, 39.3 to 150.0 and 4.2 to 15.2 kg ha^{-1}, respectively. The total highest K uptake (150.0 kg $ha-^{1}$) was observed in treatment T_6 which was statistically similar with treatments T_4 (136.2kg ha^{-1}), T_5 (140.1 kg ha^{-1}) and the lowest was found in treatment T_1, (absolute control).

All the yield contributing characters under study were significantly influenced by the treatments. Generally, treatment T_5 (100% of estimated K + full dose of NPS) performed the best result and T, (absolute control) did the worst. It was observed that there were significant and positive relationship between grain yield and yield contributing characters. Among the treatments, T_5 treatment gave the highest benefit-cost ratio (7.58). The second highest benefit-cost ratio was found in treatment T_4 (7.36). The minimum benefit-cost ratio was observed in treatment T_1, (6.90). Status of water soluble, exchangeable, non-exchangeable and total K of post-harvest soils were found lower compared to the initial soils after one cropping cycle (Table 8). Thus, the use of 140 kg N ha-1, 20 kg P $ha-^{1}$, 80 kg K ha^{-1}, 20 kg S ha^{-1}, 3 kg Zn ha^{-1} and 2 kg B ha^{-1} for boro rice were found to be more effective and beneficial for the farmer. However, further investigation is necessary to confirm these findings.

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