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Article

Effects of reduced rates of phosphorus and sulphur on the growth and yield of BRRI dhan29

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Abstract: Balanced fertilization is a pre-requisite for better rice production and it is necessary to determine optimum combination of nutrient elements for application. An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Boro season to investigate the effects of reduced rates of phosphorus (P) and sulphur (S) on the growth, yield, nutrient content and uptake by rice. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and eight treatments viz. T_1: Control, T_2: Recommended Fertilizer Dose (RFD), T_3: RFD -20% P, T_4: RFD-40% P, T_5: RFD-20% S, T_6: RFD-40% S, T_7: RFD-20% PS and T_8: RFD-40% PS. The recommended fertilizer doses were 125 kg N ha^{-1}, 25 kg P ha^{-1}, 70 kg K ha^{-1}, 15 kg S ha^{-1} and 3 kg Zn ha^{-1} supplied from urea, TSP, MoP, gypsum and zinc sulphate, respectively. There was significant effect of reduced rates of P and S fertilizers on rice yield compared to control. The highest grain yield of 5.10 t ha^{-1} and straw yield of 7.02 t ha^{-1} were recorded from treatment T_2 (RFD) that produced the maximum values of all the yield components and the highest content and uptake of nutrients. The performance of T_2 and T_3 (RFD - 20% P) was statistically similar in producing yield parameters, yields, nutrient contents and uptake by rice. Again, 20% reduced rate of S (T_5) or of P and S (T_7) caused significant yield reduction, poor yield parameters and less nutrient uptake compared to T_2. Thus, the recommended fertilizer dose and the treatments where 20% P was reduced from the RFD are equally efficient in increasing yield as well as enhancing nutritional quality of rice. This reduction of chemical fertilizer could help lessen the cost of rice production with decreasing environmental risk.

Keywords: Reduced use, fertilizer dose, grain and straw yields, nutrient content and uptake, rice

1. Introduction

In Bangladesh, rice is the staple food of about 150 million people of Bangladesh providing nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country (BBS, 2018). Importantly, about 80% of the total cultivable land is used for production of rice that contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh (BBS, 2018).Out of total 36.4 million metric tons rice production in this country during the year 2018/19, boro, aman and aus accounted for 53.8, 38.6 and 7.6%, respectively (Ahmed and Bakhtiar, 2020).

Soil is the store house of plant nutrients. Plants derive 14 essential nutrient elements from the soil (White and Brown, 2010). Among the plant nutrients, phosphorus (P) is a major essential plant nutrient element that plays a vital role in several physiological processes viz. photosynthesis, respiration, energy storage and cell division etc. and is an important structural component of nucleic acids (DNA and RNA), enzymes and co-enzymes (Chang *et al.*, 2007; Amanullah, 2011; Vahed *et al.*, 2012). For rice plants, P stimulates early root growth and development, encourages more active tillering and promotes early flowering, maturity and good grain development. So, to achieve maximum rice yields, it is essential to have sufficient content of P in soil.

Phosphorus fertilizer is one of the key inputs for increasing crop yield and nutrient concentration of rice (Dastan *et al.,* 2012). However, P accumulation in cultivated soils is a concern for non-point environmental pollution and for efficiency of P resources as a result of excessive P inputs (Li *et al.,* 2010). Phosphorus accumulation in the soil due to excessive P applications can cause a risk of P loss and contribute to eutrophication of surface waters (Xi *et al.,* 2016). The application of P fertilizer either in excess or less than optimum rate affects both yield and quality of crops to a remarkable extent. Again, sulphur (S) is another essential macronutrient for plants which plays a vital role in metabolic reactions including protein and oil synthesis, formation of chlorophyll and activation of enzymes (Singh *et al.*, 2012). Increasing S levels in rice improves leaf area index, tiller number, dry matter production, harvest index and sulphur content and uptake in rice (Chandel *et al.*, 2003; Ram *et al.*, 2014). In recent years, S deficiency has been receiving much attention as a major limiting factor for wetland rice and so, in fertilizer schedule, it is commonly included (Islam *et al.*, 2009). Sulphur deficiency affects not only the growth and yield of rice by reducing leaf and tiller number, plant height, panicle length and dry weight but also the protein quality through its effect on the synthesis of certain amino acids such as cysteine and methionine. The use of almost S free fertilizer such as urea and triple super phosphate (TSP) may be an important reason for widespread occurrence of S deficiency problem. So, to get high grain yield and to attain maximum profitability, the appropriate fertilizer input in rice is necessary (Khuang *et al.*, 2008).
Large scale use of chemical fertilizers has created a potential health hazard, reduced microbial population and earthworm activities, affecting soil health and reduced utility of water bodies for men, animals and fishes (Bhuiyan and Karim, 1999; Savci, 2012; Chandini *et al.*, 2019). Global environmental pollution can be lessened to some extent by application of reduced rates of chemical fertilizers. Moreover, chemical fertilizers are likely to be even more costly in near future. The actual recommended rates of P and S fertilizer not only maintain soil fertility for sustainable agriculture but also save part of the cost of crop production. Considering these points, the present study was undertaken to investigate the effects of reduced rates of P and S fertilizers on the growth, yield, nutrient content and uptake by rice for sustainable and profitable food production in Bangladesh.

2. Materials and Methods

2.1. Experimental site and soil

The experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during rabi season. The experimental site belongs to Sonatala series under the AEZ-9 (Old Brahmaputra Floodplain) and the soil was silt loam in texture having pH 6.2, organic matter content 1.18%, total N 0.09%, available P 17.6 ppm, available K 24.9 meq/100 g soil and available S 13.76 ppm.

2.2. Treatments and experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments having three replications. The treatments were T_1 (control), T_2 (RFD), T_3 (RFD – 20% P), T_4 (RFD – 40% P), T_5 (RFD – 20% S), T_6 (RFD – 40% S), T_7 (RFD – 20% PS), and T_8 (RFD – 40% PS). Each replication was represented by a block and each block was divided into eight unit plots for the selected treatment. The treatments were randomly distributed to unit plots in each block. There were 24 unit plots and the size of unit plot was 4 m × 2.5 m. The spacing between blocks was 1m and between plots was 0.5 m.

2.3. Land preparation and seedling transplanting

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. BRRI dhan29, a high yielding variety of rice was used as a test crop in this experiment. Forty day old seedlings were transplanted in the experimental plots by maintaining a distance of 20 cm from row to row and 20 cm from plant to plant. Three seedlings were used in each hill.

2.4. Fertilizer application

The doses of N, P, K, S and Zn were 180, 24, 76, 12 and 1.5 kg ha^{-1}, respectively following the Fertilizer Recommendation Guide (FRG, 2018) in the form of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc oxide, respectively. All the fertilizers except urea were applied as basal during final land preparation as per treatments. Urea was applied in three equal splits as top dressing. The first installment was applied at 15 days after transplanting (DAT) i.e. at seedling establishment stage, second installment at 30 DAT i.e. at maximum tillering stage and third installment at 50 DAT i.e. panicle initiation stage of rice.

2.5. Intercultural operations

Some intercultural practices such as irrigation, weeding, drainage, pest control etc. were performed as and when necessary to ensure and maintain the normal growth of the crop.

2.6. Harvesting

The test crop was harvested at full maturity. The grain yield was obtained on 14% moisture basis while the straw yield was recorded on sundry basis. Five hills were randomly selected from each plot of the block and data on growth and yield parameters including plant height, number of effective tillers per hill^{-1}, panicle length, number of filled grains panicle^{-1} and 1000-grain weight were recorded.

2.7. Preparation and analysis of plant samples

The representative grain and straw samples were dried in an oven at 65°C for about 48 hours and then ground by a grinding machine. The ground samples were passed through a 20-mesh sieve, stored in paper bags and finally kept in desiccators for chemical analysis. The contents of N, P, K and S in plant samples were determined following semi-micro Kjeldahl method (Bremner and Mulvaney, 1982), modified Olsen method (Olsen *et al.*, 1954), NH_4OAc extraction method (Knudsen *et al.*, 1982), and $CaCl_2$ extraction method (Williams and Steinbergs, 1959), respectively. The nutrient uptakes were calculated from the yield (kg ha^{-1}) and nutrient content (%) data.

2.8. Collection, preparation and analysis of initial soil samples

The initial soil samples were collected at a depth of 0-15 cm from the surface by means of auger from each plot of the blocks. After removing weeds, plant roots, stubbles, stones, etc., the collected soil samples were air-dried at room temperature, mixed thoroughly, crushed, sieved through a 20-mesh sieve and preserved in clean plastic bags for subsequent chemical and mechanical analyses. Particle size analysis of soil was performed by hydrometer method (Black, 1965) and the textural classes were determined by plotting of the values for % sand, % silt and % clay to the Marshall's Triangular Coordinate following the USDA system. Soil pH (1:2.5 soil-water) was measured by glass electrode pH meter method (Jackson, 1973) and organic matterwas determined by Walkley and Black method (Walkley and Black, 1934). Total N was measured by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982), available P by Olsen method (Olsen *et al.*, 1954), available K by flamephotometer after extraction with 1N NH_4OAc at pH 7.0 (Knudsen *et al.*, 1982), available S by extracting soil samples with $CaCl_2$ solution (0.15%) and by measuring turbidity by spectrophotometer (Williams and Steinbergs, 1959) method.

2.9. Statistical analysis

The collected data on various parameters were statistically analyzed using the MSTAT–computer package program (Russell, 1986) in order to get the level of significance and the differences among treatment means were adjudged by Duncan's New Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Effect of different treatments on the yield components of rice (BRRI dhan29)

Yield contributing characters such as plant height, panicle length, number of effective tiller hill^{-1} and number of filled grains panicle^{-1} of BRRI dhan29 were significantly affected by different treatments under study while weight of 1000-grain remained statistically unaffected (Table 1). The tallest plant of 82.84 cm, maximum number of effective tillers hill^{-1} of 13.20, highest panicle length of 24.84 cm, maximum number of filled grains panicle^{-1}of 153 and highest weight of 1000-grain of 22.21 g were found in T_2 (100% RFD) which were statistically identical to those observed in T_3 (RFD – 20% P). The treatment T_3 produced the second highest values for plant height (82.23 cm), number of effective tillers hill^{-1} (13.09), panicle length (24.26 cm), number of filled grains panicle^{-1} (92.33) and 1000-grain weight (22.21 g). On the other hand, the shortest plant of 64.17 cm, minimum number of effective tillers hill^{-1} of 9.17, lowest panicle length of 20.32 cm, minimum number of filled grains panicle^{-1}of 78 and lowest weight of 1000-grain of 20.05 g were found in T_1 (control). The positive responses of P and S application on the growth and yield parameters of rice were also reported by Massawe and Mrema (2017), Islam *et al.* (2016) and Sharma *et al.* (2009). The results showed that use of recommended doses of chemical fertilizers was more efficient in improving yield parameters of rice. However, 20% reduced rate of P performed more or less similar with recommended doses. Our results are partially or fully accorded to the findings of Hasan *et al.* (2008) and Baki *et al.* (2015) who reported statistically similar yield parameters from recommended fertilizers and from 20% reduction of N, P or K from recommended doses. The significance of P and S on improving growth and yield parameters of rice was demonstrated by several researchers (Ali *et al.*, 2004; Yosef *et al.*, 2013; Uddin *et al.*, 2014).

3.2. Effect of different treatments on the yield of rice

Reduced rates of P and S fertilizers exerted significant effects on grain yield and straw yield of BRRI dhan29 (Table 2). The highest grain yield of 5.10 t ha^{-1} and straw yield of 7.02 t ha^{-1}were recorded in T_2 (100% RFD) and the lowest grain yield of 3.40 t ha^{-1} and straw yield of 4.30 t ha^{-1} were found in T_1 (control). The treatment T_3 (RFD – 20% P) showed statistically similar behavior with T_2 and it produced the second highest grain yield of 5.02 t ha^{-1} and straw yield of 6.97 t ha^{-1}. The percent increase in rice yield over control ranged from 25.29 to 50 for grain and 44.88to 63.26 for straw where T_2 gave the highest yield increase over control. In case of both grain yield and straw yield, the treatments may be ranked in the order $T_2 > T_3 > T_5 > T_7 > T_6 > T_4 > T_8 > T_1$. The results of the present study are also in agreement with the findings of many researchers. The present findings are in partial agreement with those of Hasan *et al.* (2008) and Baki *et al.* (2015) where recommended fertilizers were applied but these yields did not vary significantly with the yields observed in the treatments with the reduction of P or K or S at the rate of 20% from the recommended doses. Sharma *et al.* (2009) reported that the grain yield of rice increased significantly when the rate of P application was increased from 0 to 35 kg P ha^{-1} either as DAP or MRP. Islam *et al.* (2016) and Kalala *et al.* (2016) revealed that the application of higher dose of S exerted pronounced effect in producing higher grain and straw yields of rice.

3.3. Effect of different treatments on P content and uptake in grain and straw of rice

Phosphorus content in grain and straw of BRRI dhan29 was significantly influenced by the different treatments (Table 3). In case of grain, the highest P content (0.29%) was found in treatments T_2 (100% RFD), T_3 (RFD - 20% P) and T_5 (RFD -20% S) which were statistically identical to treatment T_7 (RFD -20% PS) that recorded 0.28% P. In case of straw, the maximum P content (0.17%) was observed in T_2 which was not statistically different from those found in T_3, T_5 and T_7 treatments. The lowest contents of P in grain (0.22%) and straw (0.75%) were noted in T_1 where no fertilizer was applied. Phosphorus uptake in rice was also significantly affected by various treatments under study (Table 3). The maximum uptake of P in grain (13.60 kg ha^{-1}), straw (10.83 kg ha^{-1}) and total (24.43 kg ha^{-1}) were also recorded in T_2 which was identical to those observed in T_3. Treatment T_3 produced the second highest uptake of P in grain (12.99 kg ha^{-1}), straw (10.28 kg ha^{-1}) and total (23.27 kg ha^{-1}). On the other hand, the control treatment recorded the lowest uptake of P in grain (6.91 kg ha^{-1}), straw (5.03 kg ha^{-1}) and total (11.94 kg ha^{-1}). The reduction of recommended doses of fertilizers by 20% did not significantly reduce P content and uptake in rice which was demonstrated by Baki *et al.* (2015) and Hasan *et al.* (2008). Phosphorus rates and application timings significantly affect phosphorus uptake in rice (Sanusan *et al.*, 2009). The favorable effect of higher availability of P in soil and different levels of P applied ondry matter production and content ultimately reflectinsignificant increase in P uptake by rice (Archana *et al.*, 2017).

3.4. Effect of different treatments on S content and uptake in grain and straw of rice

Reduced use of P and S fertilizers had no significant effect on S content in rice but exerted significant influence on S uptake by rice grain, straw and in total (grain + straw) (Table 4). The maximum S content in grain (0.14%) was recorded in T_2, T_3 and T_5 treatments whereas the highest S content in straw (0.12%) was noted in T_2 and T_5 treatments. The minimum S contents in grain (0.12%) and straw (0.10%) were recorded in control (T_1). On the other hand, S uptake in grain, straw and total varied from 3.64 to 661.25, 112.88 to 555.59 and 336.15 to 1116.84 kg ha^{-1}, respectively. On the other hand, the values for grain S uptake, straw S uptake and total S uptake ranged from 3.10 to 6.48, 3.86 to 7.36 and 7.50 to 13.93 kg ha^{-1}, respectively. For S uptake (grain, straw and total), the highest values were obtained from T_2 (100% RFD) which were identical to those found in T_3 (RFD - 20% P).The lowest values of S uptakes (grain, straw and total) were observed in control (T_1). Similar with our findings, Baki *et al.* (2015) and Hasan *et al.* (2008) showed no significant reduction in S content and uptake in rice with 20% reduction of recommended fertilizer doses. Chandel *et al.* (2003) and Islam *et al.* (2016) showed that S content in rice grain and straw was significantly increased by the application of higher rates of S.

Table 1. Effect of reduced rates of P and S on the yield components of rice.

Treatments	Plant height (cm)	Number of effective tillers hill^{-1}	Panicle length (cm)	Number of filled grains panicle^{-1}	1000-grain weight (g)
T_1	64.17f	9.17c	20.32e	78.00f	20.05
T_2	82.84a	13.20a	24.84a	92.33a	22.21
T_3	82.23ab	13.09a	24.26ab	91.67ab	22.09
T_4	77.68c	11.30b	23.82b	90.00b	20.79
T_5	80.15b	11.08b	24.19ab	90.33b	21.30
T_6	79.61b	10.62bc	23.80b	88.33c	20.77
T_7	74.53d	11.19b	22.98c	86.00d	20.65
T_8	73.12de	10.30bc	21.66d	82.00e	20.53
CV%	2.03	1.04	2.41	3.77	1.02
SE (±)	1.68	0.31	0.45	1.73	0.22
Level of significance	**	**	**	**	NS

Figures in a column having common letters do not differ significantly at 1% level of significance. CV (%) = Coefficient of variation; SE (±) = Standard error of means; ** = Significant at 1% level of probability.

Table 2. Effect of reduced rates of P and S on the grain and straw yield of rice.

Treatments	Grain yield (t ha^{-1})	Increase over control (%)	Straw yield (t ha^{-1})	Increase over control (%)
T_1	3.40g	-	4.30f	-
T_2	5.10a	50	7.02a	63.26
T_3	5.02ab	47.65	6.97ab	62.09
T_4	4.48e	31.76	6.29e	46.28
T_5	4.93b	45	6.86b	59.53
T_6	4.65cd	36.76	6.33de	47.21
T_7	4.78c	40.59	6.47cd	50.57
T_8	4.26f	25.29	6.23e	44.88
CV%	2.97	-	2.81	-
SE (±)	0.74	-	0.93	-
Level of significance	**	-	**	-

Figures in a column having common letters do not differ significantly at 1% level of significance. CV (%) = Coefficient of variation; SE (±) = Standard error of means; ** = Significant at 1% level of probability.

Table 3. Effect of reduced rates of P and S on P content and uptake by rice.

Treatments	P content (%)		P uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1	0.22d	0.13c	6.91d	5.03d	11.94f
T_2	0.29a	0.17a	13.60a	10.83a	24.43a
T_3	0.29a	0.16ab	12.99a	10.28a	23.27ab
T_4	0.25c	0.15b	10.08c	8.36c	18.44de
T_5	0.29a	0.16ab	12.79ab	9.83ab	22.62b
T_6	0.27b	0.15b	11.52b	8.90bc	20.42cd
T_7	0.28ab	0.16ab	11.92b	9.45b	21.37c
T_8	0.25c	0.14bc	9.70c	8.10c	17.80e
CV%	3.21	1.07	4.91	2.11	3.73
SE (±)	0.16	0.11	1.49	1.34	1.99
Level of significance	**	**	**	**	**

Figures in a column having common letters do not differ significantly at 1% level of significance. CV (%) = Coefficient of variation; SE (±) = Standard error of means; ** = Significant at 1% level of probability.

Table 4. Effect of reduced rates of P and S on S content and uptake by rice.

Treatments	S content (%)		S uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1	0.12	0.10	3.64d	3.86d	7.50e
T_2	0.14	0.12	6.48a	7.45a	13.93a
T_3	0.14	0.11	6.25a	7.12ab	13.37ab
T_4	0.13	0.11	5.41c	6.22bc	11.62c
T_5	0.14	0.12	6.13ab	6.97b	13.10b
T_6	0.13	0.11	5.69bc	5.94c	11.64c
T_7	0.13	0.11	5.90b	5.81c	11.71c
T_8	0.13	0.10	4.95c	5.88c	10.82d
CV%	1.21	1.49	3.77	2.89	2.04
SE (±)	0.08	0.07	0.96	1.06	1.41
Level of significance	NS	NS	**	**	**

Figures in a column having common letters do not differ significantly at 1% level of significance. CV (%) = Coefficient of variation; SE (±) = Standard error of means; NS = Not significant; ** = Significant at 1% level of probability.

4. Conclusions

From the present study, it is distinct that the recommended dose of fertilizers provided the highest yield of BRRI dhan29 with better nutrient content and uptake. As the recommended fertilizer 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 20% reduction of P from the recommended doses are equally efficient in producing grain and straw yield as well as improving nutritional quality of rice. On the other hand, 20% reduction of S or both of P and S from the recommended rates were not similarly effective with recommended fertilizer dose as they produced comparatively lower yield, poor yield characters and nutrient uptake in rice. Imbalanced use of chemical fertilizers is costly in terms of nutrient loss from soil mining, decline in food supply and loss of soil fertility. Application of fertilizers at reduced rates would be helpful to promote the eco-friendly environment and reduce the input cost of rice production. However, a thorough investigation with other rice varieties is needed to draw a reasonable conclusion.

Conflict of interest

None to declare.

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