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SOIL SCIENCE

Performance of Improved Sulphur Formulations on Growth, Yield, and Nutrient Uptake of Rice in an Inceptisol of Uttar Pradesh

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ABSTRACT

A field investigation was conducted on sandy loam soil of Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif* season of 2016, with an aim to study the effect of levels of improved sulphur (S) formulations on growth and productivity of rice grown in Gangetic alluvial of Uttar Pradesh. It was revealed that the growth parameters, yield attributes, yield, and nutrient uptake were significantly influenced by the application of improved S fertilizers. Application of improved S, Gromor Rapid Blue® @ 10 kg acre^{-1} produced the highest dry matter accumulation, grain weight panicle^{-1}, test weight, and straw yield. Maximum grain yield (4.85 t ha^{-1}) was obtained in 7.5 kg Gromor Rapid Blue® acre^{-1}, which is about 18% higher than the control. In case of uptake of nutrients by grain, highest uptake of N and S was recorded with 10 kg Gromor Rapid Blue® acre^{-1}, and highest uptake of P and K was obtained with 7.5 kg Gromor Rapid Blue® acre^{-1}. According to the study, application of Gromor Rapid Blue® @ 7.5 kg acre^{-1} is recommended for better growth and yield of rice in soils of Varanasi.

Highlights

- Adoption of improved S formulations for overcoming the challenges of S deficiency
- With each successive levels of improved S fertilizers there is enhancement of growth and yield of rice
- Highest chlorophyll content, grain yield, and grain P and K uptake were recorded with application of Gromor Rapid Blue® @ 7.5 kg acre^{-1}

Keywords: Improved sulphur fertilizers, rice, growth, yield, nutrient uptake

The importance of sulphur (S) nutrition in crops for their growth and development has been receiving increased attention in recent years. Sulphur plays an important role in the synthesis of S-containing amino acids (cystine, cysteine, and methionine), proteins, vitamins, chlorophyll, oils, etc. Although essential for plants, proper monitoring in the fertilization process was not initiated in the past which resulted in depletion of S reserves. Widespread deficiencies of S have been attributed to S mining by the use of high analysis or S-free fertilizers and continuation of rice-wheat or rice-mustard cropping system. Such deficiencies have been reported in the eastern Uttar Pradesh (Singh and Kumar 2012), and analysis of large number (2334) of surface (0-15 cm) soil samples collected from the eastern region of the state indicated S-deficiency to the tune of 50% (Singh *et al*. 2015). Thus, significant reduction in quality and yield of several crops could be noticed (Pandey *et al*. 2015). Application of S from suitable sources is one of the key measures to optimize S use for sustainable crop productivity (Aulakh 2003). Sulphur requirement in crops were mainly met through single super phosphate (SSP) and ammonium sulphate (AS) fertilizers or through micronutrient fertilizers (zinc

sulphate, copper sulphate, etc.). There are few studies regarding the use of improved S fertilizers for enhancing the productivity and quality of crop species. Some field experiments have been carried out using commercial grade fertilizers like elemental S, bentonite S, gypsum, phospho-gypsum, and pyrites. Thus, there are large numbers of S sources available in the country, and their efficiency in crops (rice, wheat, mustard, groundnut, etc.) needs to be evaluated.

In India, Coromandel International Limited was first to launch their product Gromor Sulphur® as S fertilizer, having 90% elemental S (S°) and 10% bentonite clay in pastille form. Improved package of practices is must for rice which is the staple food of people living in Southeast Asia and tropical and subtropical regions of the world, i.e. more than half of the world population. The present investigation was carried out to study the effect of different levels of improved S formulations on growth, yield, and nutrient uptake of rice grown in Gangetic alluvial (Inceptisol) of eastern Uttar Pradesh. Both S variants from Coromandel International Limited, viz., Gromor Sulphamax® and Gromor Rapid Blue® are 90% S° coated with 10% bentonite clay, but differ in appearance, shape, size, and oxidation rate of the pastilles or granules.

MATERIALS AND METHODS

Study site

The field experiment was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India (25°18′ N, 83°03′ E; altitude of 80.7 m above mean sea level) during *kharif* season of 2016. The experimental soil is classified as Inceptisol (Typic Ustochrept) having pH of 7.56, EC of 0.27 dSm^{-1}, organic carbon of 3.9 g kg^{-1}, sand of 48.52%, silt of 29.28%, clay of 22.20% (sandy loam in texture), available N of 187.7 kg ha^{-1}, available P of 18.9 kg ha^{-1}, available K of 214 kg ha^{-1} and available S of 15.9 kg ha^{-1}. The total rainfall received during the cropping season was 918.6 mm. The average monthly maximum and minimum temperature ranged from 30.4 to 34.0°C and 16.6 to 26.7°C, respectively.

Field experiment

The experiment was laid out in a randomized block design with six treatments having four replications. The improved S fertilizers received from Coromandel International Limited (Hyderabad, India) were varied into different levels, and thus, the six treatments adopted for rice consisted of T_1: control (without S), T_2: Gromor Sulphamax® @ 10 kg $acre^{-1}$, T_3: Gromor Rapid Blue® @ 5kg $acre^{-1}$ T_4: Gromor Rapid Blue® @ 7.5 kg $acre^{-1}$, T_5: Gromor Rapid Blue® @ 10 kg $acre^{-1}$, and T_6: micronized S @ 3 kg $acre^{-1}$. Micronized S (S 80% WDG) was purchased from local market as in many areas, farmers apply this formulation in soil for nutrition purpose. Micronized S powder was mixed with soil before applying to the field. The recommended dose of N, P_2O_5, K_2O @ 150, 60, 60 kg ha^{-1} was applied through urea, diammonium phosphate (DAP), and muriate of potash (MOP), respectively. At the time of transplanting, half dose of N and K and full dose of P were applied in the field. The remaining amount of K was given only at tillering stage, but N was applied in two splits (½ + ½) at tillering and panicle initiation (PI) stages of rice. S fertilizers were applied four days before the transplanting of rice. The top 2.5 cm of puddled field were thoroughly mixed with S fertilizers. Sambamasuri sub 1 variety of rice was sown in nursery on 14th June 2016 and the seedlings of rice were transplanted on 18th July 2016 in individual plot size of 25 sq m (5 m × 5 m) at 20 cm × 20 cm spacing. About 3 to 4 seedlings per hill were used for the purpose. A thin film of water was maintained up to 15 days after transplanting (DAT) and latter irrigated as per requirement. Weedings were done at 20 and 45 DAT. The plants were harvested after 120 DAT.

Studies on growth and yield attributes of rice

The required data were collected at tillering, PI, anthesis, and harvesting stages of rice. Plant height was measured from the surface of soil to the tip of plant with the help of a meter scale. The Soil Plant Analysis Development (SPAD, Minolta Camera Co., Osaka, Japan) chlorophyll meter was used for measuring the chlorophyll content (SPAD value) of the fully expanded uppermost leaves. Fresh green leaves were used for computing leaf area index (LAI) in leaf area meter. Root samples collected by using core sampler were subjected to cleaning with

tap water and drying with tissue paper, were used for root fresh weight. Thousand (1000) grain weight was used as test weight. Grain yield was measured at 12% moisture content.

Plant analysis

Plant samples harvested at maturity were washed sequentially with 0.2% detergent solution, 0.1 N HCl, and finally with double distilled water. The samples were dried at 60°C for 48 h in a hot air oven. Dried grains were finely grounded. Nitrogen (N) content in grains were estimated by Kjeldahl digestion method. Di-acid mixture (HNO_3:$HClO_4$::9:4) was used for estimating total phosphorus (P) by vanadomolybdate yellow colour method (Jackson 1973), total potassium (K) by flame photometer (Jackson 1973), and total S by turbidimetric method (Chesnin and Yien 1951). The uptake of nutrients (N, P, K, and S) in grain was calculated by multiplying grain yield with their respective concentrations.

Statistical analysis

The data obtained from the field experiment were subjected to one-way analysis of variance (one-way ANOVA) with the help of OPSTAT software. Critical difference (CD) at 5% level was used to determine statistically significant differences between the treatment means.

RESULTS AND DISCUSSION

Growth parameters

The study revealed that improved S formulations had significant influence on the growth parameters of rice (Table 1 and 2). Root fresh weight was

Table 1: Effect of improved sulphur formulations on root fresh weight, dry weight, and plant height at various growth stages of rice

Treatment	Root fresh weight (g m^{-2})				Dry matter accumulation (g m^{-2})				Plant height (cm)			
	Tillering	PI	Anthesis	Harvesting	Tillering	PI	Anthesis	Harvesting	Tillering	PI	Anthesis	Harvesting
T_1: Control	246.8	504.0	838.3	740.3	57.0	308.3	694.6	1064.6	55.0	87.0	99.0	104.7
T_2: Gromor Sulphamax® @ 10 kg $acre^{-1}$	325.8	696.0	956.8	881.0	68.5	328.0	750.9	1383.7	58.7	89.7	104.0	109.7
T_3: Gromor Rapid Blue® @ 5 kg $acre^{-1}$	296.8	683.3	937.8	877.3	65.9	349.5	890.2	1263.5	58.7	89.7	101.0	109.7
T_4: Gromor Rapid Blue® @ 7.5 kg $acre^{-1}$	365.0	685.0	1113.3	1030.0	78.1	355.4	1011.4	1590.7	60.3	91.7	104.0	110.7
T_5: Gromor Rapid Blue® @ 10 kg $acre^{-1}$	377.3	718.3	1116.8	1059.3	78.8	367.4	1053.6	1627.3	61.3	92.7	104.7	112.0
T_6: Micronised S @ 3 kg $acre^{-1}$	273.0	566.8	900.0	850.0	59.0	316.7	766.8	1199.8	57.0	88.7	102.0	106.7
SEm±	11.09	6.74	33.31	16.76	0.80	6.77	2.66	8.71	0.68	0.55	0.81	0.84
CD (*P*=0.05)	33.72	20.51	101.33	50.99	2.43	20.59	8.09	26.49	2.05	1.68	2.47	2.55

Table 2: Effect of improved sulphur formulations on chlorophyll content, leaf area index, and number of tillers at various growth stages of rice

Treatment	Chlorophyll content (SPAD value)			Leaf area index			Tillers m^{-2}		
	Tillering	PI	Anthesis	Tillering	PI	Anthesis	Tillering	PI	Anthesis
T_1: Control	38.6	37.2	28.6	0.6	1.6	2.6	165	173	173
T_2: Gromor Sulphamax® @ 10 kg $acre^{-1}$	40.8	38.2	34.3	0.8	1.9	3.8	173	188	190
T_3: Gromor Rapid Blue® @ 5 kg $acre^{-1}$	39.8	37.7	32.4	0.7	1.8	3.7	192	182	183
T_4: Gromor Rapid Blue® @ 7.5 kg $acre^{-1}$	42.3	40.0	35.5	0.9	1.9	3.9	177	190	190
T_5: Gromor Rapid Blue® @ 10 kg $acre^{-1}$	41.3	39.7	35.3	1.0	2.1	4.0	175	193	193
T_6: Micronised S @ 3 kg $acre^{-1}$	39.6	38.1	31.3	0.7	1.7	2.9	169	183	184
SEm±	0.37	0.38	0.91	0.04	0.04	0.11	3.29	1.99	1.34
CD (*P*=0.05)	1.12	1.14	2.78	0.12	0.11	0.33	10.01	6.04	4.09

Table 3: Effect of improved sulphur formulations on different yield attributes and yield of rice

Treatment	Panicles m^{-2}	Panicle length (cm)	Grains $panicle^{-1}$	Grain weight $panicle^{-1}$ (g)	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
T_1: Control	261.0	19.2	165.0	1.60	16.2	4.12	6.52	38.73
T_2: Gromor Sulphamax® @ 10 kg $acre^{-1}$	288.0	21.4	179.8	2.38	17.0	4.53	9.31	32.72
T_3: Gromor Rapid Blue® @ 5 kg $acre^{-1}$	275.3	19.9	168.0	2.34	17.1	4.36	8.27	34.49
T_4: Gromor Rapid Blue® @ 7.5 kg $acre^{-1}$	301.0	22.1	182.5	2.55	18.7	4.85	11.05	30.52
T_5: Gromor Rapid Blue® @ 10 kg $acre^{-1}$	295.0	21.7	182.3	2.74	18.6	4.77	11.50	29.32
T_6: Micronised S @ 3 kg $acre^{-1}$	271.3	19.7	165.8	2.30	16.8	4.29	7.70	35.77
SEm±	3.68	0.39	1.79	0.05	0.13	0.05	0.03	0.24
CD (*P*=0.05)	11.20	1.17	5.44	0.14	0.41	0.14	0.10	0.74

found to increase rapidly up to anthesis stage, and after that decreased, irrespective of the treatments. However, dry matter yield and plant height continued to increase till harvesting stage (Table 1). Increasing the levels of S enhanced these parameters. Highest values were obtained with the application of Gromor Rapid Blue® @ 10 kg $acre^{-1}$, but they were statistically at par with 7.5 kg Gromor Rapid Blue® $acre^{-1}$ in most of the cases. Dry matter accumulation (total above ground biomass production) recorded at harvest showed the maximum (1627.3 g m^{2-}) and minimum (1064.6 g m^{2-}) dry matter yield with the application of Gromor Rapid Blue® @ 10 kg $acre^{-1}$ and no application of S, respectively. The results of plant height are in conformity with the findings of Ram *et al*. (2014a). According to Ram *et al*. (2014b) increase in metabolic activities of plant with S application is the cause of enhanced growth parameters.

Chlorophyll content and tillers m^{-2} increased up to PI stage, while leaf area index continued to increase up to anthesis stage of rice (Table 2). In PI stage, application of Gromor Rapid Blue® @ 7.5 kg $acre^{-1}$ attained the highest chlorophyll content (40.0), and

the lowest (37.2) was found in the plants where no S fertilizer was added, when measured with the SPAD meter. Significantly higher LAI was recorded at anthesis stage with the application of improved S fertilizers over no S application. Increased LAI of rice with S application was reported by Chandel *et al*. (2003) and Singh *et al*. (2012). Shivay *et al*. (2014) observed the highest LAI with bentonite S used as a source of S over other sources, viz., single superphosphate (SSP), gypsum, and elemental S. The effect of improved S fertilizers on number of tillers was also noticed. Application of Gromor Rapid Blue® @ 10 kg acre^{-1} resulted 11.56% increase in tillers m^{-2} over control (without S) after the tillering stage.

Yield attributing parameters and yield

Gromor Sulphamax® applied @ 10 kg acre^{-1} had a similar effect to that of 10 kg Gromor Rapid Blue® acre^{-1} on panicles m^{-2}, panicle length, and grains panicle^{-1} (Table 3). Significant effect of Gromor Rapid Blue® application @ 10 kg acre^{-1} over other treatments was recorded on grain weight panicle^{-1} and straw yield. Application of Gromor Rapid Blue® @ 10 kg acre^{-1} remained statistically on par with 7.5 kg Gromor Rapid Blue® acre^{-1} in terms of all yield attributing parameters and yield except grain weight panicle^{-1} and harvest index. Highest grains panicle^{-1} and test weight was reported by Shivay *et al*. (2014) with bentonite S application in rice. Maximum grain yield (4.85 t ha^{-1}) was obtained in 7.5 kg Gromor Rapid Blue® acre^{-1}, which was at par with the application of Gromor Rapid Blue® @ 10 kg acre^{-1}, and produced about 18% higher grain yield than the control. Kumar *et al*. (2014) and Islam *et al*. (2016) observed more or less similar trend in grain and straw yield that with increasing the levels of S there is enhancement of these parameters. Harvest index decreased with S application, and similar observations were also reported by Oo *et al*. (2007).

Nutrient acquisition

The concentration and uptake of N in rice grain increased with increase in levels of S (Table 4). Results showed that the effect of 7.5 and 10 kg Gromor Rapid Blue® acre^{-1} on uptake of nutrients was similar. P, K, and S uptake with the application of Gromor Sulphamax® @ 10 kg acre^{-1} were at par with the application of Gromor Rapid Blue® @ 7.5 and 10 kg acre^{-1}. Increase in N, P, K, and S uptake by rice grain with S addition was reported by several researchers (Oo *et al*. 2007; Dixit *et al*. 2012; Islam *et al*. 2016). Positive effect of S on nutritional status (N, P, and S) of maize was also observed by Mehta *et al*. (2005). The metabolism of N and S are linked to each other, and both are involved in protein synthesis, thus maintenance of N:S ratio in crops is very important. Shivay *et al*. (2014) found increased N and S concentration in rice with the application of bentonite S. The grain S uptake increased from 3.71 to 8.59 kg ha^{-1} with the addition of S levels. The results are in agreement with the findings of Kumar *et al*. (2014). Further, Rakesh *et al*. (2016)

Table 4: Effect of improved sulphur formulations on nutrient acquisition by rice grain at harvest

Treatment	N (%)	N uptake (kg ha^{-1})	P (%)	P uptake (kg ha^{-1})	K (%)	K uptake (kg ha^{-1})	S (%)	S uptake (kg ha^{-1})
T_1: Control	1.11	45.90	0.31	12.78	0.41	16.91	0.09	3.71
T_2: Gromor Sulphamax® @ 10 kg acre^{-1}	1.36	61.77	0.38	17.22	0.45	20.39	0.18	8.31
T_3: Gromor Rapid Blue® @ 5 kg acre^{-1}	1.24	54.24	0.34	14.66	0.44	19.18	0.15	6.69
T_4: Gromor Rapid Blue® @ 7.5 kg acre^{-1}	1.37	66.32	0.37	18.14	0.46	22.34	0.16	7.94
T_5: Gromor Rapid Blue® @ 10 kg acre^{-1}	1.43	68.13	0.36	17.20	0.45	21.50	0.18	8.59
T_6: Micronised S @ 3 kg acre^{-1}	1.15	49.23	0.33	14.31	0.43	18.47	0.12	5.16
SEm±	0.01	0.67	0.01	0.41	0.01	0.41	0.01	0.26
CD (*P*=0.05)	0.04	2.03	0.03	1.26	0.02	1.26	0.02	0.78

reported higher uptake and better use efficiency of S with application of bentonite S in mustard. The S° fertilizers are slow release fertilizers. But the availability of S is dependent upon the factors affecting the oxidation of S° such as S° particle size, moisture content of soil, presence of S oxidizing microbes in soil, etc. (Degryse *et al*. 2016). These fertilizers have the advantage of providing a prolonged supply of S during the crop growth season and also in the succeeding crop season with negligible leaching losses (Riley *et al*. 2000).

CONCLUSION

The study revealed that improved bentonite S fertilizers can be adopted by the farmers for successful production of rice, especially in the S deficient areas of Varanasi region (eastern Uttar Pradesh). These are slow release fertilizer which can supply S as per the crop demands. Based on the findings, application of Gromor Rapid Blue® @ 7.5 kg acre^{-1} is recommended for enhancing the productivity and S use efficiency of rice.

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