Intern. J. Trop. Agri., Vol. V, No. 2, pp. 93–101 (June 1987)

EFFECT OF SULPHUR ON RICE UNDER FLOODED CONDITION

R. ISLAM, M. S. A. HOSSAIN, A. S. HOWLADAR, A. ISLAM, R. MANDAL AND S. M. IMAMUL HUQ

Department of Soil Science

Dhaka University, Dhaka-2, Bangladesh

(Received : May 14, 1986; Accepted : April 10, 1987)

ABSTRACT

BR-3 variety of rice responded significantly to applications of sulphur either in the form of gypsum or as elemental S. The response was more prominent in the soil where the available S content was below the critical level (9.5 ppm). Gypsum appeared to have a more beneficial effect than elemental sulphur on all the growth parameters. An increase of Ca 8% in grain yield was obtained with an application of 30 kg S ha^{-1} as gypsum. Although sulphur contents in various parts of rice plant varied significantly with different rates of S application, the N and P contents in them remained unaffected. The maximum content of S was recorded in plants receiving S between 30 and 40 kg ha^{-1}. Grain S content was significantly affected by S addition from both the sources. The changes in yield parameters as well as nutrient elements were significantly affected by S application.

The importance of sulphur application as a plant nutrient has until recently been underestimated. This was partly due to the contributions of the element to soil from the atmosphere and through phosphatic fertilizers, particularly the superphosphates (Sein *et al.*, 1969). With increase in the application of high analysis fertilizers containing little or no sulphur, and with the use of insecticides and fungicides containing lesser sulphur contents, the incidental addition of sulphur to soils has shown a gradual decrease (Ensminger and Freney, 1966). At the same time, greater amounts of sulphur are being removed through higher crop yields without being equally replenished. Although a limited amount of sulphur is being added each year with rainfall, the quantity is inadequate in non-industrialized areas to meet crop needs. Consequently, sulphur deficiencies are being reported with increasing frequency throughout the world (Elkins and Ensminger, 1971).

Recent observations at the experimental field of Bangladesh Rice Research Institute as well as at farmers' levels indicated sulphur deficiency in Joydebpur area of Bangladesh. Under certain conditions the deficiency was found to be the limiting factor for satisfactory rice yields (Alam and Karim, 1972). The widespread deficiency of sulphur in different soils of the country is also reported in the Chandpur Irrigation Project Area. Considering the fact that many soils are low in sulphur and a planned programme for sulphur fertilization is necessary, a pot experiment was carried out to study the effect of sulphur on growth, yield and chemical composition of rice under flooded condition with two soils varying widely in their organic matter and S contents.

MATERIAL AND METHODS

Two soils representing the Naraibag and Kalma series were collected to a depth of 0-15 cm from rice growing areas. Some of the physical and chemical properties of the soil samples are presented in Table 1.

Greenhouse Experiment

4.5 kg (2 mm) of air-dried soils were thoroughly mixed with 1.5 kg of washed sand and were placed in earthen pots of 8 l sizes. A basal dose of N (urea), P (TSP) and K (MP) at the rates of 60, 30 and 30 kg ha^{-1}, respectively, was used. Two different sources of sulphur viz., gypsum and elemental S, were used to add equivalent amount of 10, 20, 30 or 40 kg S ha^{-1} in pots of respective treatment. Control pots did not receive any S. A separate treatment containing only calcium oxide (70.5 kg ha^{-1}) was included to compare the additional effect, if any, of calcium from gypsum. Elemental S was allowed to oxidize for two weeks before the soils were submerged. Transplantation of two 5 weeks' old healthy seedlings of BR-3 variety of rice in each pot was done five days after submergence of the soils in order to bring the soils into equilibrium. There were three replicates of each of the treatments. The pots were arranged randomly in the greenhouse. Water level in the pots was maintained at 3 cm above soil surface throughout the growing season that lasted for about three months. The pots were kept weed free.

Plant samples (one hill per pot) were collected at flowering stage and at the harvesting stage. At maturity, the grain yield was measured. Soil samples from each pot were collected to measure the changes in available S contents in soil.

Analytical Methods

Soil texture, pH and organic matter content were determined by standard and conventional techniques. Nitric-perchloric acid digestible sulphur of plants and grains were determined by the turbidity method of Chesnin and Yien (1950) as modified by Sakai (1978). The same method was used to determine the calcium di-hydrogen phosphate (500 ppm) extractable sulphur from soil. The acid digest was also used for phosphorus and potassium determinations. Nitrogen was estimated from Kjeldahl's digest by alkali distillation (Jackson, 1958).

RESULTS AND DISCUSSION

Available Sulphur

Concentrations of available sulphur collected at flowering and at maturity stages varied significantly with rates of S application (Tables 2 and 3). Amount measured in Naraibag soil was considerably higher than that in Kalma soil. This was related to the native S contents of the two soils.

TABLE 1

Some physical and chemical properties of the soils

Name of the soils	Textural class	pH	CEC meq/ 100 g	Organic matter (%)	Total nutrients (%)				Available nutrients (ppm)				
					N	P	K	S	N	P	K	S	Ca
Naraibag	Silty loam	6.7	11.36	2 05	0.15	0.07	0.72	0 035	26 0	9.4	143.2	32.9	326 0
Kalma	Silty clay	7.7	10.04	0.94	0 06	0.05	0.48	0 021	16.3	6.2	68 2	9.5	208 4

TABLE 2

Effect of gypsum and elemental sulphur on the yield and chemical composition of rice at different stages of growth in Naraibag soil

Treatments		Gypsum S					Elemental S				CaO	LSD at
(kg/ha)		0	10	20	30	40	10	20	30	40	70.5	1% level
At flowering straw (g/hill)		5.96	8.60	9.35	8.55	7.82	7.42	7.76	8.05	8.91	7.25	NS
Tissue Content (%)	S	0.13	0.17	0.16	0.17	0.17	0.17	0.17	0.18	0.18	0.14	0.011
	N	1.00	1.06	1.08	1.22	1.11	1.09	1.02	1.10	1.21	1.03	NS
	P	0.26	0.28	0.37	0.33	0.31	0.27	0.33	0.28	0.28	0.26	NS
	K	1.48	1.65	1.64	1.69	1.65	1.62	1.66	1.70	1.68	1.50	0.05
Available ppm	S	28.3	43.0	49.1	52.7	64.4	39.3	46.7	52.7	53.6	32.1	18.9
At maturity straw (g/hill)		4.39	6.33	5.01	5.60	5.61	4.75	4.79	5.86	5.26	4.44	NS
Grain (g/hill)		3.20	3.27	3.32	3.26	3.31	3.28	3.26	3.19	3.20	3.17	NS
Tissue Content (%)	S	0.11	0.12	0.12	0.13	0.13	0.12	0.13	0.13	0.13	0.11	0.023
	N	0.58	0.63	0.64	0.76	0.74	0.61	0.63	0.70	0.68	0.60	NS
	P	0.15	0.15	0.17	0.20	0.16	0.16	0.19	0.15	0.15	0.15	NS
	K	1.51	1.72	1.84	1.77	1.75	1.65	1.75	1.89	1.78	1.54	0.05
Grain (%)	S	0.09	0.12	0.12	0.13	0.13	0.12	0.12	0.12	0.12	0.09	0.02
Available ppm	S	21.1	28.6	33.3	35.9	38.4	27.3	39.4	38.4	41.8	22.3	4.7

NS = Non Significant

TABLE 3

Effect of gypsum and elemental sulphur on the yield and chemical composition of rice at different stages of growth in Kalma soil

Treatments	Gypsum S					Elemental S				CaO	LSD at
(kg/ha)	0	10	20	30	40	10	20	30	40	70.5	1% level
At flowering straw (g/hill)	4.24	7.09	7.55	7.64	6.44	5.78	5.64	6.20	7.38	5.29	0.673
S	0.13	0.16	0.17	0.17	0.18	0.16	0.17	0.18	0.19	0.14	0.028
Tissue N	0.90	0.93	1.01	1.02	1.06	0.94	1.01	0.88	0.93	0.92	NS
Content P	0.20	0.27	0.28	0.31	0.30	0.25	0.27	0.28	0.25	0.21	NS
(%) K	1.39	1.51	1.54	1.52	1.50	1.53	1.57	1.58	1.56	1.40	0.030
Available ppm S	12.4	15.8	18.9	20.0	32.3	15.8	17.4	18.9	21.8	14.0	3.36
At maturity straw (g/hill)	4.16	4.52	4.86	5.50	4.82	4.61	4.73	4.97	4.78	4.11	0.297
Grain (g/hill)	2.84	2.90	2.93	3.08	3.00	2.92	3.12	3.01	2.89	2.79	0.04
S	0.09	0.12	0.13	0.13	0.14	0.12	0.12	0.13	0.14	0.09	0.111
Tissue N	0.50	0.60	0.61	0.63	0.59	0.54	0.62	0.55	0.61	0.52	NS
Content P	0.12	0.14	0.17	0.16	0.18	0.13	0.14	0.14	0.16	0.13	NS
(%) K	1.40	1.54	1.57	1.51	1.53	1.57	1.59	1.54	1.35	1.42	0.03
Grain S (%)	0.075	0.104	0.109	0.121	0.121	0.092	0.109	0.112	0.119	0.080	0.023
Available ppm S	11.3	12.4	16.4	17.6	20.9	14.5	16.9	17.6	20.4	9.00	4.56

Effect of Sulphur Application on the Growth and Yield of Rice

Application of sulphur in any form did not induce any significant change in the height and number of tillers (data not shown) in either of the soils; neither did it show any significant effect on straw and grain yield of rice in Naraibag soil (Table 2). However, in Kalma soil, straw yields at both the stages of growth were significantly affected by sulphur application (Table 3). Sulphur application in this soil at the rate of 30 kg ha^{-1} as gypsum produced a maximum yield of 7.64 g and 5.50 g straw $hill^{-1}$ at the flowering and maturity stages, respectively. The maximum grain yield was obtained at the application rate of 20 kg S ha^{-1} as elemental sulphur and 30 kg S ha^{-1} as gypsum.

Aiyar (1945) reported that sulphur added to rice in field plots tended to double the weight of grain. Increase in rice yields in Burma, India, Japan, Russia and the United States with addition of sulphur containing fertilizers has been reported (Beaton, 1966). In Bangladesh, sulphur application has been found to increase yield from 0.3 to 2.2 t ha^{-1} of rice at farmers' level (Hoque and Hobbs, 1978). These authors reported that rice yields increased by 72 and 43 per cent due to S application from ammonium sulphate and magnesium sulphate, respectively. Similar results have also been reported by Ray *et al.* (1978) from the experiment at the Bangladesh Rice Research Institute Farm. The results obtained by Islam (1978) indicated that either ammonium sulphate or gypsum or a combination of the two greatly improved the grain yield over urea. It has to be remembered, however, that response of rice to applied sulphur fertilizer is regulated to a large extent by the rice cultivars (Blair and Till, 1981).

Effect of Sulphur on the Chemical Composition of Rice

The contents of sulphur, nitrogen, phosphorus and potassium in rice tissue are presented in Tables 2 and 3. Sulphur in rice at both the stages of growth varied significantly with rates of sulphur application. The maximum content of tissue sulphur at flowering and at maturity stage in Naraibag soil was observed when the plants received S at the rate of 30 kg ha^{-1}. However, in Kalma soil this value was observed at 40 kg ha^{-1} application. S application did not have any significant effect on the nitrogen and phosphorus concentration of plant tissue (Tables 2 and 3). However, application of sulphur appeared to have influenced the K contents of plants. Elemental sulphur when applied at the rate of 30 kg ha^{-1} induced the highest tissue K content except in Kalma soil at maturity stage where the same was obtained at 20 kg S ha^{-1} application. Such a situation could arise due to increased metabolic activity involving K related enzymes.

Sulphur application, irrespective of the sources, caused a significant increase in grain sulphur content (Tables 2 and 3). The maximum S content in grains on

Naraibag soil was 0.13% obtained at 30 kg S ha^{-1} application rate. The same in the Kalma soil was 0.12% obtained at the same application rate. The values for grain S at no sulphur application were 0.09 and 0.096, respectively, for Naraibag and Kalma soils. Sen (1938) reported that 0.096 to 0.105 per cent sulphur in rice grain showed deficiency symptoms Aiyar (1945) found that 0.081 to 0.094 per cent S in rice grain showed deficiency symptoms. Based on these values, it is apparent that both Naraibag and Kalma series soils fall in the deficient zones. Application of 10 kg S ha^{-1} from any of the sources could remove this deficiency in the Naraibag soil. But in the Kalma soil the application rate has to be just the double this amount to remove any deficiency of S.

Relationships between Soil and Plant Sulphur Contents and Yields of Straw, Grain and Plant Nutrients

Correlation coefficients between straw yield and available sulphate as well as plant sulphur were found to be significant within 5% confidence limits for both the soils (Table 4) indicating that both the soils responded to S applications. However, grain yield and available sulfate as well as plant sulphur was correlated significantly only in the Kalma soil—the soil deficient in available sulphur (9.5 ppm). In the Naraibag soil that contained appreciable amount of available S, no significant correlations were obtained among these parameters. The findings suggested that soils having

TABLE 4
Correlation coefficients between sulphur and yields (straw and grain) and nutrients

Correlation between	Simple correlation coefficients (r)	
	Naraibag soil	Kalma soil
Straw yield and available S	$+0.562^{5}$	$+0.726^{3}$
Straw yield and plant S	$+0.716^{3}$	$+0.839^{2}$
Grain yield and available S	$+0.401^{ns}$	$+0.686^{1}$
Grain yield and plant S	$+0.362^{ns}$	$+0.766^{2}$
Grain S and plant S	$+0.928^{1}$	$+0.915^{1}$
Plants S and available S	$+0.687^{4}$	$+0.832^{2}$
Plant N and plant S	$+0.880^{1}$	$+0.745^{3}$
Plant P and plant S	$+0.244^{ns}$	$+0.513^{ns}$
Plant K and plant S	$+0.591^{5}$	$+0.804^{2}$

^{1}, ^{2}, ^{3}, ^{4}. and ^{5} represent level of significance at 0.1, 1, 2, 5 and 10%, respectively.
ns=Non significant.

less than 13.0 ppm available sulfate would respond to application of sulphur and this value could be considered the critical level under submerged conditions. Wang (1976) reported the critical level of sulfate sulphur to be about 10 ppm in calcium dihydrogen phosphate extracts. The present observations suggest that rice plants will respond better to applied sulphur in soils low in native available sulphur. This is further substantiated by the fact that in Kalma soil, sulphur content of straw and grain correlated with available sulphur content better than it was found in the Naraibag soil (Table 4). Values for single correlation coefficient revealed that application of S improved the nitrogen and phosphorus status slightly and potassium status appreciably. Increased concentration of S in the rice tissue was perhaps instrumental in stimulating certain metabolic activities with the result of increased N, P and K uptake. Similar views have been expressed by authors like Walker and Adams (1958) and Mengel and Kirkby (1978) while dealing with S nutrition in plants.

Introduction of CaO together with sulphur treatment showed no significant effect on any of the parameters studied indicating that the soils under study did not have any Ca deficiency. The use of elemental S in lowland rice cultivation is possible if sufficient time is allowed to oxidize the added S before the soils are submerged. Use of elemental S in lowland rice has been reported by Ismunadji and Zulkarnaini (1978) who reported that elemental S was as effective in correcting S deficiency in rice soils as potassium sulfate, ammonium sulfate or calcium sulfate. In the light of the present study, it would be suggestive to use gypsum preferentially over elemental S considering its easy availability, readybility to use and non-contributory effect of additional Ca on rice yield.

REFERENCES

Aiyar, S P 1945. A chlorosis of paddy (*Oryza sativa*) due to sulphate deficiency. *Curr. Sci.* (India) **14** : 10-11.

Alam, S. M. and Karim, K. 1972. Sulphur content in rice plant. *Pak. J. Sci. Res.* **24** : 222-26

Beaton, J. D. 1966. Sulphur requirements of cereals, trees, fruits, vegetables and other crops. *Soil Sci.* **101** : 267-82.

Blair, G. J. and Till, A. R. 1981. Sulphur in South East Asia. *Sulphur in Agriculture* **5**:

Chesnin, L. and Yien, C. H. 1950. Turbidimetric determination of available sulphates. *Soil Sci. Soc. Amer. Proc.* **15** : 149-51.

Elkins, D. M and Ensminger, L. E. 1971. Effect of soil pH on the availability of adsorbed sulphate. *Soil Sci. Soc. Amer Proc.* **35** : 931-34.

Ensminger, L. E. and Freney, J R. 1966. Diagonistic techniques for determining sulphur deficiencies in crops and soils. *Soil Sci.* **101** : 283-90.

Hoque, M. Z. and Hobbs, R. P. 1978. Response of rice crops to added sulphur at BRRI station and nearby project area. Workshop on sulphur nutrition in rice. *BRRI Pub. No.* 41 : 15-19.

Islam, A. J. M. A. 1978. Sulphur deficiency symptoms, corrective measures and results obtained. Workshop on sulphur nutrition in rice. *BRRI Pub. No.* **41** : 20-28.

Ismunadji, M. and Zulkarnaini, I. 1978. Sulphur deficiency in lowland rice in Indonesia. *Sulphur in Agriculture* **2** : 17-19.

Jackson, M. L. 1958. *Soil Chemical Analysis.* Prentice Hall Inc. Englewood Cliffs, N. J., U. S. A.

Mengel, K. and Kirkby, E. A. 1978. Principles of Plant Nutrition. Int. Potas. Inst., Berne, Switzerland. pp. 329-46.

Ray, A. C., Shah, A. I., Aziz, T. and Biswas, S. K. 1978. Sulphur requirements of rice and sulphur status of some rice soils and plants of selected locations. Workshop on sulphur nutrition in rice. *BRRI Pub. No.* **41** : 60-75.

Sakai, H. 1978. Some analytical results of sulphur deficient plants, soil and water. Workshop on sulphur nutrition in rice. *BRRI Pub. No.* **41** : 35-59.

Sein, E. C., Caldwell, A. C. and Rehm, G. W. 1969. Sulphur response by alfalfa on a sulphur deficient soil. *Agron. J.* **61** : 368-71.

Sen, A. T. 1938. Further experiments in the occurrence of depressed yellow patch of paddy in the Mandalay Farm. Burma Dept. Agr. Report. 35-36.

Walker, T. W. and Adams, A. F. R. 1958. Studies on soil organic matter. *Soil Sci.* **85** : 307-18.

Wang, C. H. 1976. Sulphur fertilization of rice. Food and Fertilizer Technology Centre for the Asia and Pacific Region, Dec. 1976.