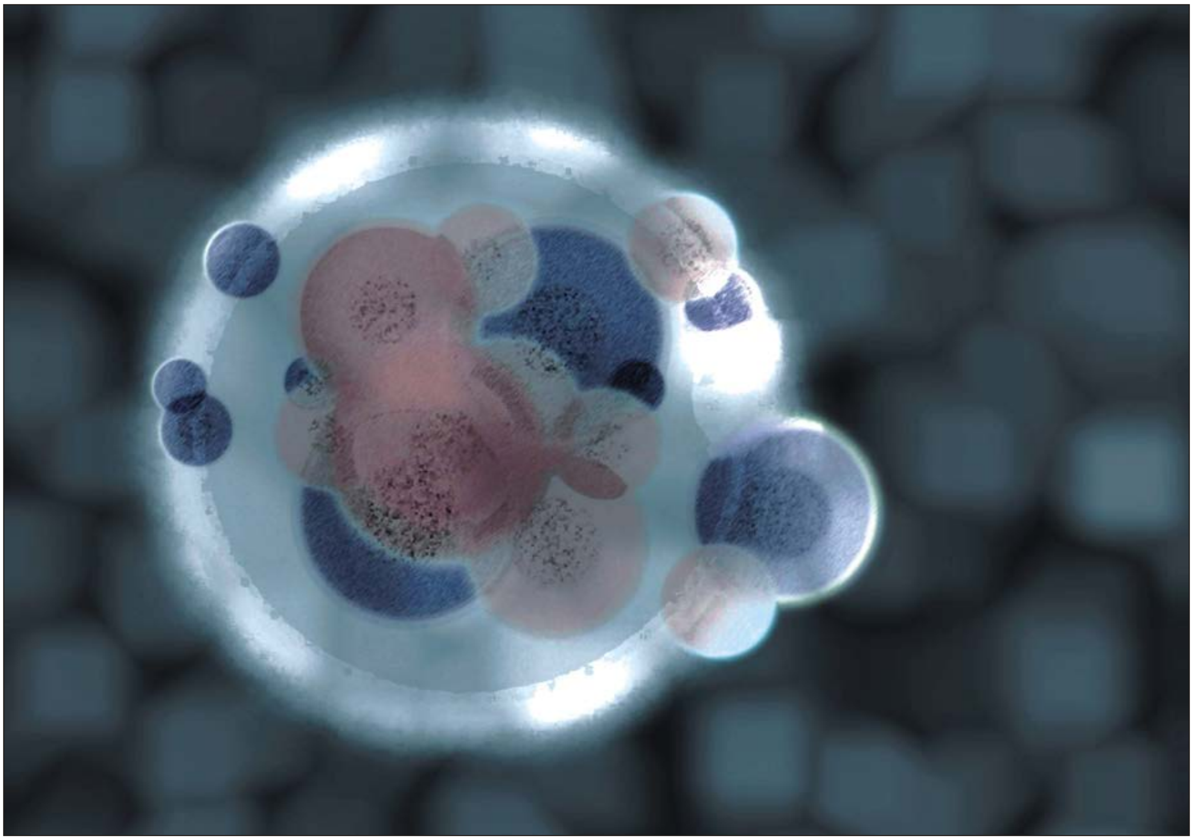

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Response of Sunflower to Sulfidic Materials and Magnesium Sulfate as Sulfur Fertilizer

[1,2]Md. Harunor Rashid Khan, [2]S.M. Abu Syeed, [2]Farook Ahmed,
[2]A.H.M. Shamim, [1]Yoko Oki and [1]Tadashi Adachi
[1]Department of Environmental Management Engineering, Faculty of Environmental Science and Technology, Okayama University, Okayama 700-8530, Japan
[2]Department of Soil, Water and Environment, Faculty of Biological Sciences, University of Dhaka, Dhaka 1000, Bangladesh

Abstract: The potentiality and effectiveness of Sulfidic Materials (SM) and Magnesium Sulfate (MS) as sources of sulfur in relation to the growth of sunflower (*Helianthus annus* L.) cultivated in two sulfur deficient soils were evaluated under pot experiment. The SM and MS were applied at the rates of 0, 25, 50 and 75 kg S ha^{-1}. The best growth and yield performance of sunflower were attained by the SM_{75} treatment in both the Sirajgonj (e.g., seed yield: 43.2 g/plant) and Gazipur (31.3) soils, followed by the SM_{50} (30.3 Sirajgonj, 22.4 Gazipur) > MS_{75} (25.2 Sirajgonj, 22.3 Gazipur) treatments. The application of SM_{75} increased (increased over control = IOC) the flower head diameter and seed yield by 80 and 169% in the Sirajgonj soil and 77 and 182% IOC in the Gazipur soil, respectively. But the equivalent amount of MS_{75} increased those parameters by 41, 56% and 21, 100% IOC in both the soils, respectively. Almost similar and significant ($p \leq 0.05$) effects were observed for the other yield parameters of sunflower grown in both the soils. The application of SM increased the organic matter from 0.66 to 1.26% in the Gazipur soil and from 0.77 to 0.98% IOC in the Sirajgonj soil, regardless of the application rates. The application of SM also enhanced sulfur and organic matter status of the soils and these increments were more pronounced in both the soils till the final harvest at maturity of sunflower, reflecting a good indication for its long term use instead of the chemical fertilizer.

Key words: Effectiveness of sulfidic materials, growth and yield of sunflower, sulfur deficient soils

INTRODUCTION

Sunflower is a recognized worldwide for its beauty; it is also an important source of food. Sunflower oil is a valued and healthy vegetable oil; its seeds are enjoyed as a healthy, tasty snack and nutritious ingredient to many foods (http://www.sunflowernsa.com). Sunflower became one of the most important agricultural crops due to its improved breeding and tolerance to abiotic stress (Tonev, 2006). He also stated that the introduction and mass production of new genotypes replaced the main hybrid. These conditions implied large-scale research with the sunflower under diverse conditions. Year round cultivation of this crop and easy oil extraction methods make the crop popular to the farmers (Berry and Schmidt, 2001). Sunflower can be a profitable first crop in a warm-season double cropping system and the environment of Bangladesh is suitable for its growth. Sunflower is becoming increasingly popular among the farmers in Bangladesh as an important edible oil-yielding crop. Edible oils are in short supply in Bangladesh and sunflower can contribute substantially to overcome this shortage. It is noted that about 7 M ha of lands are reported to consist of sulfur deficient soils in the Northern region of Bangladesh (SRDI, 1999). Sunflower requires more sulfur and the application of sulfur fertilizers to the soils can instantly supply sulfur to crops but the fertilization should be done for each crop, which is not a good practice for the soils as well as environments. Therefore, a suitable and sustainable source of sulfur is indispensable. Khan *et al.* (2002) reported that the SM or layers of Acid Sulfate Soils (ASSs) deserve attention to use these SM for the reclamation of saline, alkaline, calcareous or sulfur deficient soils and ASSs themselves.

The ASSs can cause severe environmental degradation (http://www.epa.vic.gov.au). It has been recently estimated that these affect some 100 M ha of land world-wide (Sheeran, 2003). Since the sulfide layers in ASSs can exert severe effects on surrounding ecosystems, immediate steps should be taken to consider

Corresponding Author: Md. Harunor Rashid Khan, Department of Environmental Management Engineering, Faculty of Environmental Science and Technology, Okayama University, Okayama 700-8530, Japan Tel/Fax: 086-251-8993, 090-37463279

these soils further (Khan *et al*., 2002). Delayed effects of potential chemicals stored in the SM resulted in harmful effects, like a chemical time bomb on the associated environments (Khan and Adachi, 1999). Potential ASSs may have high pH like 6 to 7 does not mean that the soils are safe because at that situation it may create H_2S, Fe, some organic acids and CO_2 problems (Kabir, 2005). The weathering of sulfidic overburdens and mine spoils present the same problems. Orndorff and Daniels (2002) reported that exposure of SM from road construction presents a number of technical, environmental and social problems. The SM were detected at depths of 10 to 40 cm in the different pockets of actual ASSs of Cox' Bazar coastal plains in Bangladesh (Khan *et al*., 2005). The potentiality and effectiveness of these SM for an alternative use deserve attention and have been examined in this study. These SM behave like an acute tumor/cyst in the soil body. If it is neglected, it will have exerted severe effects not only on the surrounding agricultural ecosystems but also on the aquatic and other environments. Therefore, it is very essential and high time to save the ASSs as well as soil-plant-water environments by removing the SM and this derelict SM can be used as hypothesized for sulfur deficient soils. The reclamation of these soil materials may be difficult but essential (Khan *et al*., 2006). Successful reclamation of the ASSs or SM may result in the development of productive fields for crop growth. While poor soil reclamation may lead to creation of unfavorable soil conditions for crop growth and formation of ASSs, the real problem in the coastal tidal flat plain areas. Against this background, the present study was considered to evaluate the potentiality and effectiveness of the SM or ASSs compared with MS ($MgSO_4$) as sulfur fertilizer in relation to the production of sunflower in sulfur deficient soils, which is not only a new approach for the alternative use of SM but also might solve the problems of the utilization and management of the ASSs and sulfur deficient soils.

MATERIALS AND METHODS

Soil collection and analyses: Bulk samples of two sulfur deficient soils (depth: 0-20 cm) of Kamarkhand series (Sirajgonj soil) and Kalma series (Gazipur soil) were collected, respectively from the districts of Sirajgonj and Gazipur in Bangladesh. The SM (Cheringa ASS) used for this study was obtained from the surface soil (depth: 0-20 cm) at Dulhazara in the Cox' Bazar district. This SM contained yellow mottles resemble jarosite throughout the layer. Selected physical and chemical properties of the pre- and post harvested soils were analyzed according to the methods of Klute (1986). The samples obtained from each soil were stored under field-moist conditions (by putting the soil samples and the SM into polyethylene bags in an air-tied box) just prior to laboratory analyses, when the sub-samples were air-dried and crushed to 2 mm before analyses (Table 1).

Pot experiment: A pot experiment was conducted in the greenhouse at the premises of the Department of Soil, Water and Environment, University of Dhaka during April to August 2002 to evaluate the effectiveness of SM and MS as sulfur fertilizer in relation to growth and yield performance of sunflower grown in the sulfur deficient soils. The experiment consisted of 14 treatments and 3 replications for each treatment. The doses of SM and MS were selected based on the sulfur requirement of the country as reported by BARC (1997). The experiments were set up in a completely randomized design. The experimental treatments were as follows:

Sirajgonj soil (Kamarkhand series):

T_1 = Control (no application of MS and SM),
T_2 = MS_{25} ($MgSO_4$ at the rate of 25 kg S ha^{-1}),
T_3 = MS_{50} (MS; 50 kg S ha^{-1}),
T_4 = MS_{75} (MS; 75 kg S ha^{-1}),
T_5 = SM_{25} (Sulfidic materials; 25 kg S ha^{-1}),
T_6 = SM_{50} (SM; 50 kg S ha^{-1}),
T_7 = SM_{75} (SM; 75 kg S ha^{-1})

Gazipur soil (Kalma series):

T_8 = Control,
T_9 = MS_{25} (MS; 25 kg S ha^{-1}),
T_{10} = MS_{50} (MS; 50 kg S ha^{-1}),
T_{11} = MS_{75} (MS; 75 kg S ha^{-1}),
T_{12} = SM_{25} (SM; 25 kg S ha^{-1}),
T_{13} = SM_{50} (SM; 50 kg S ha^{-1}),
T_{14} = SM_{75} (SM; 75 kg S ha^{-1}).

Eight kilo gram of air-dried and screened (5 mm sieve) soil was placed in each earthen pot (Size: 32 cm height/ 24 cm diameter). The soil in each pot was fertilized with N, P and K at the rates of 60, 30 and 20 mg kg^{-1} as urea, TSP and muriate of potash (MP), respectively. The full dose of TSP and MP and half of urea were mixed with the soil during pot preparation. The remaining urea was applied in equal splits, one at the flower initiation and the other at the active flowering stages of the sunflower. As per treatments, the soils in the pots were also subjected to the application of SM and MS at the rates of 0, 25, 50 and 75 kg S ha^{-1} during pot preparation. Six healthy and uniform seeds were sown in each pot from which four healthy and uniform seedlings were allowed to grow in each pot. The intercultural operations were performed as required. The soils in the pots were irrigated by tap water (pH 6.5 and EC 0.05 S m^{-1}) whenever necessary, to maintain the soil under moist to dry conditions required for the growth of sunflower.

Plant collection and analysis: Plant height, shoot or straw dry matter yield and leaf area were determined at 30, 60, 90 and 125 days after seed sowing. Two plants per pot were harvested each time at 1 cm above the soil surface. At maturity, straw dry matter, flower head diameter, seed per head, seed yield and weight of thousand grains of sunflower were determined. The level of significance of the different treatments was determined using Duncan's New Multiple Range Test (DMRT) and Least Significant Difference (LSD) techniques (Zaman *et al.*, 1982). The typical analyses obtained at different growth stages of sunflower are presented in Table 2-5 and Fig. 1.

RESULTS AND DISCUSSION

Sulfidic Materials (SM): The SM collected from the surface (depth: 0-20 cm) of an acid sulfate soil (Typic Sulfic Halaquept, detailed: Kabir, 2005) showed a silty clay loam texture with pH values of 3.4 (0.02 M $CaCl_2$: lab) and 4.2 (Field), indicating that the SM had probably accumulated a large amount of pyrite which had produced some H_2SO_4 in the laboratory by oxidation. The EC, available and total sulfur and content of organic matter in the SM were very high while the base saturation and available P contents were very low (Table 1). The content of Ca in SM was low compared with the Mg content, presumably be due to occasional flooding with sea water with the high Mg content (Khan *et al.*, 1994).

Pre- and post harvested soils: The Gazipur soil and the Sirajgonj soil had silty clay loam and silty loam textures, initial pH values of 5.0 to 5.8 and 5.9 to 6.1, respectively as determined by the different conditions. These sulfur deficient soils were subjected to the application of SM and MS in relation to the growth of sunflower. The values of pH in the post harvested soils were found to be decreased by 4 to 7 and 3 to 5% IOC in the Gazipur and Sirajgonj soils, respectively, indicating that the use of the SM to these soils showed no remarkable influences on the soil pH. On the other hand, the SM exerted strong positive effects on the contents of the initial low organic matter, N, P, available and exchangeable Mg, available and total sulfur in the soils as evinced by the striking increment of these parameters by 27 to 91, 10 to 13, 17 to 30, 49 to 65, 11 to 27, 172 to 187 and 53 to 103% IOC in both the soils (Table 1), which was due to the high nutrient status of the applied SM. The base saturation and EC values of the soils were also increased by 6 to 9 and 54 and 73% IOC, which might be due to the high EC and contents of basic cations of the applied SM to the soils.

Sulfur and organic matter status in the soils: The content of available sulfur in the soils were found to increase by the treatments, regardless of soil conditions and the effects were significantly ($p\leq 0.05$) positive with the ahead of time (Table 2). These effects were more pronounced with the higher rates of fertilization and the striking increments were recorded with the application of SM in both the soils (Table 2). The application of SM_{50} was found almost equally effective to MS_{75} in both the soils. Regardless of fertilizer rates and soil conditions, the SM exerted best response for the available sulfur and was significantly more pronounced in the Gazipur soil (Table 3). On the other hand, the contents of total sulfur was found to increase by the treatments but decreased with the advent of time but the trend of effects were almost similar to and significant to the available sulfur in both the soils (Table 3).

The content of organic matter in both the soils was not much influenced by the application of MS through out the experimental period, whereas all the three rates of SM showed significantly ($p\leq 0.05$) positive effects on the organic matter status in both the soils and the effects were more striking with the higher rates. The effects of the treatments were more pronounced in Sirajgonj soil than the Gazipur soil (Table 3). This was due to the initial high content of organic matter in the Sirajgonj soil compared with the Gazipur soil (Table 1).

Growth and yield of sunflower: The treatments exerted significant ($p\leq 0.05$) positive effects on the growth and yield of sunflower and their effects varied not only with the kinds and amounts of treatments but also with the agronomic parameters of the sunflower, such as, plant height, dry matter production, leaf area, the flower head diameter and seed yield. The tallest plant height was attained by the application SM_{75}, followed by $SM_{50}\geq SMS_{75}$ treatments in both the soils, indicating that these treatments considerably affected by the kinds than the amounts of the treatments. The effects of the treatments were quite similar in both the soils (Fig. 1).

Table 1: Some selected properties of the soils (depth: 0-20 cm) and sulfidic materials used in the experiment

Soil properties	Sulfidic materials	Gazipur soil Before use	After use	IOC[a] (%)	Sirajgonj soil Before use	After use	IOC[a] (%)
Textural class	Silty clay loam	Silty clay loam			Silty loam		
Soil pH (Field, 1:2.5)	4.20	5.80	5.40	-6.9	6.10	5.90	-3.3
Soil pH (0.02 M $CaCl_2$, 1:2.5)	3.40	5.00	4.80	-4.0	5.90	5.60	-5.1
EC (1:5 S m^{-1})	1.60	0.13	0.20	53.8	0.11	0.19	72.7
Organic matter (g kg^{-1})	40.30	6.60	12.60	90.9	7.70	9.80	27.3
Available N (1.3 M KCl: mM kg^{-1})	3.65	0.20	0.22	10.0	0.23	0.26	13.0
Avail. P (0.002 N H_2SO_4, pH 3: mM kg^{-1})	0.11	0.12	0.14	16.7	0.10	0.13	30.0
CEC (1 M NH_4Cl: C mol kg^{-1})	18.20	17.00	17.20	1.2	14.00	14.40	2.9
Base saturation at pH 7.0 (%)	22.20	66.50	70.30	5.7	74.40	81.40	9.4
Exchangeable cations (1 M NH_4OAC)							
Sodium (flame photometer: C mol kg^{-1})	2.44	0.37	0.48	29.7	0.41	0.61	48.8
Potassium (flame photometer: C mol kg^{-1})	0.25	0.07	0.11	57.1	0.08	0.11	37.5
Calcium (AAS*: C mol kg^{-1})	0.33	6.52	6.70	2.8	6.69	6.90	3.1
Magnesium (AAS: C mol kg^{-1})	1.02	4.34	4.80	10.6	3.23	4.10	26.9
Water-soluble ions							
Sodium (flame photometer: C mol kg^{-1})	4.84	0.12	0.25	108.3	0.14	0.18	28.6
Potassium (flame photometer: C mol kg^{-1})	0.21	0.24	0.29	20.8	0.28	0.34	21.4
Calcium (AAS*: C mol kg^{-1})	0.27	3.77	3.81	1.1	6.47	6.60	2.0
Magnesium (AAS: C mol kg^{-1})	3.34	2.13	3.17	48.8	2.37	3.91	65.0
Available sulfur ($BaCl_2$: mmol kg^{-1})	244.00	0.31	0.89	187.1	0.29	0.79	172.4
Total sulfur ($BaCl_2$: mmol kg^{-1})	1656.00	15.55	31.53	102.8	13.95	21.30	52.7

*AAS = Atomic Absorption Spectrophotometer; [a]IOC = Increased Over Control

Table 2: Sulfur and organic matter contents in the Sirajgonj and Gazipur soils at different growth stages of sunflower as influenced by the application of Sulfidic Materials (SM) and $MgSO_4$ (MS) in S-deficient soils

Treatments No.	Denotation	Available-S (mM kg^{-1}) 30 days	60 days	90 days	125 days	Total-S (mM kg^{-1}) 30 days	60 days	90 days	125 days	Organic matter (g kg^{-1}) 30 days	60 days	90 days	125 days
T_1	Control	0.32d	0.31d	0.30f	0.30e	13.1f	12.3e	11.4e	11.1e	11.2d	11.1c	10.3c	10.1c
T_2	MS_{25}	0.38cd	0.44c	0.51e	0.56d	16.8d	14.4d	13.3de	12.8de	11.6d	11.8c	11.0c	10.4c
T_3	MS_{50}	0.40c	0.55bc	0.69c	0.73c	21.2c	21.0c	20.7c	20.1c	12.1c	11.4c	11.1c	10.6c
T_4	MS_{75}	0.54b	0.72a	0.82b	0.88b	31.6b	30.3b	28.8b	25.2b	11.9c	11.7c	11.4c	10.8c
T_5	SM_{25}	0.42c	0.42c	0.57de	0.72c	13.3e	12.5de	11.7e	11.3e	12.4c	12.7bc	12.2c	12.2bc
T_6	SM_{50}	0.53b	0.58b	0.81bc	0.87b	31.1b	30.1b	27.7bc	25.6b	13.3bc	13.8b	13.6bc	13.6b
T_7	SM_{75}	0.63a	0.70a	0.98a	1.00a	36.7a	35.2a	33.1b	32.8a	16.0a	16.6a	17.8a	18.0a
LSD (5%)		0.06	0.07	0.09	0.10	3.3	3.2	3.1	3.0	1.6	1.6	1.8	1.9
T_8	Control	0.34e	0.33f	0.33f	0.31e	15.0e	14.4f	12.3e	11.8e	8.7d	7.9d	7.2d	6.8b
T_9	MS_{25}	0.39de	0.46e	0.49e	0.51d	19.3d	16.6ef	14.4de	13.2de	9.1c	8.4d	7.8d	7.2d
T_{10}	MS_{50}	0.51c	0.56d	0.77d	0.82c	31.9c	31.7d	31.2c	30.9c	9.7c	8.8cd	8.3cd	8.1cd
T_{11}	MS_{75}	0.60b	0.76bc	0.89bc	0.93b	38.2bc	36.4c	33.3c	31.8c	10.2c	9.7c	9.4c	9.1c
T_{12}	SM_{25}	0.52bc	0.68c	0.77d	0.83c	31.9c	31.8d	31.1c	30.6c	11.7b	11.9b	11.2b	10.7b
T_{13}	SM_{50}	0.56b	0.81b	0.83c	0.94b	41.6b	39.3bc	37.7b	36.8b	12.2a	12.1b	11.8ab	11.3b
T_{14}	SM_{75}	0.86a	0.92a	1.10a	1.30a	47.0a	46.6a	46.1a	45.9a	12.9a	13.2a	12.9a	12.4a
LSD (5%)		0.09	0.09	0.10	0.11	4.7	4.6	4.6	4.5	1.3	1.3	1.3	1.2

In a column, means followed by a common letter(s) are not significantly different at 5% level; Sirajgonj soil (Kamarkhand series): Silty loam, pH 6.1, Organic matter = 0.77%, Total-S = 13.95 and available-S = 0.29 mM kg^{-1}; Gazipur soil (Kalma series): Silty clay loam, pH 5.8, Organic matter = 0.66%, Total-S = 15.55 and available-S = 0.31 mM kg^{-1}

Table 3: Comparison on selected typical soil parameters after harvesting the sunflower at maturity as affected by sulfidic materials and magnesium sulfate treatments in two sulfur deficient soils

Treatments	Available sulfur (mM kg^{-1}) Gazipur soil	Sirajgonj soil	G and SM mean	Organic matter (g kg^{-1}) Gazipur soil	Sirajgonj soil	G and SM mean
Control	0.31e[#]	0.30e	0.31z	6.8d	10.1d	8.5y
$MgSO_4$ (MS: kg S ha^{-1})			0.74y			9.4y
MS_{25}	0.51d	0.56d		7.2d	10.4d	
MS_{50}	0.82c	0.73c		8.1cd	10.6d	
MS_{75}	0.93b	0.88b		9.1c	10.8cd	
Sulfidic materials (MS: kg S ha^{-1})			0.94x			13.0x
SM_{25}	0.83c	0.72c		10.7b	12.2c	
SM_{50}	0.94b	0.87b		11.3ab	13.6b	
SM_{75}	1.30a	1.00a		12.4a	18.0a	
Soil mean	0.81m	0.72n		9.4n	12.2m	
LSD at 5% level =			0.10			1.4

[#]In a column and the row of soil mean followed by a common letter(s) are not significantly different at 5% level

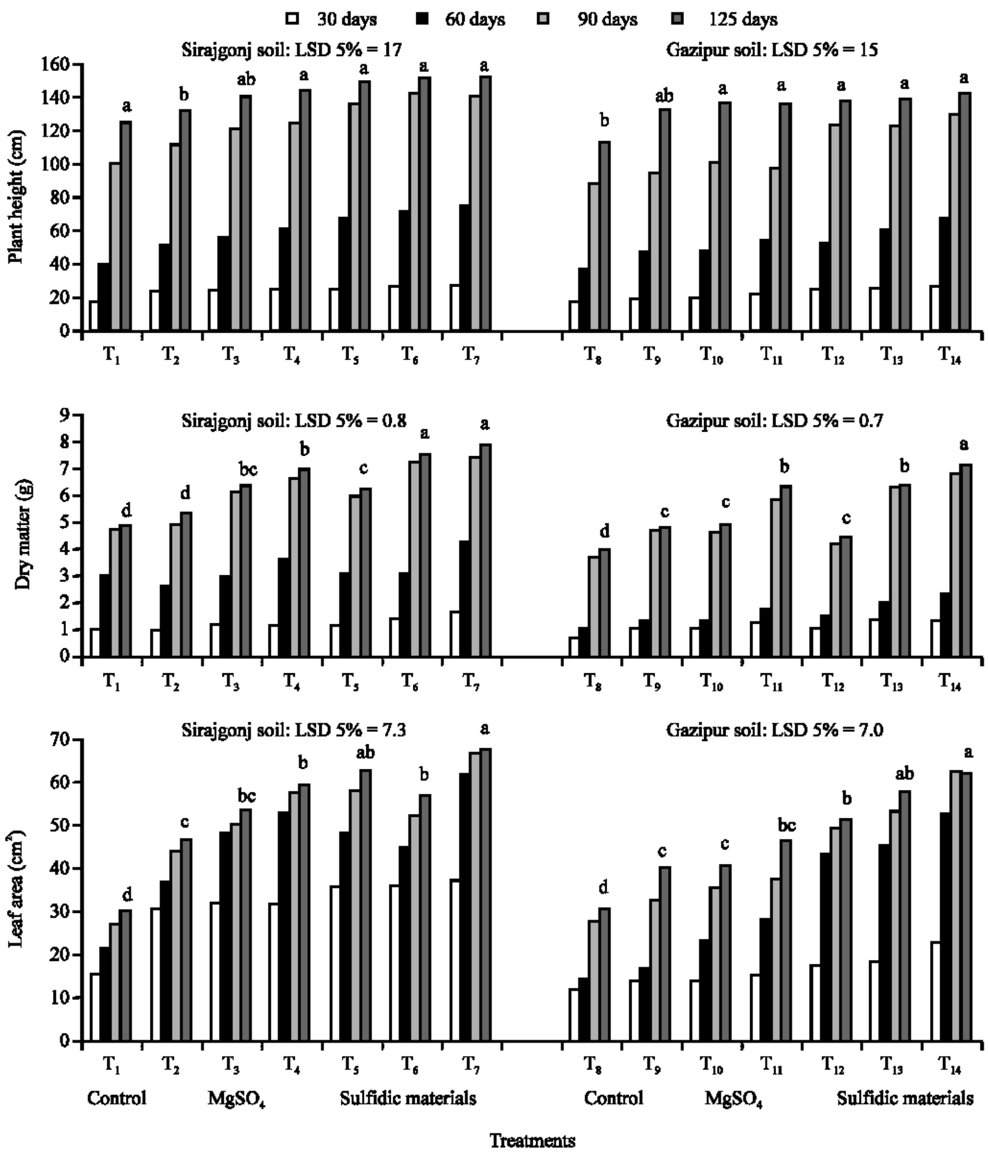

Fig. 1: Effects of sulfidic materials and $MgSO_4$ as S-fertilizer on plant height, dry matter production and leaf area of the sunflower grown on S-deficient soils

Straw dry matter production at all growth stages of the sunflower increased significantly ($p \leq 0.05$) mostly in all the treatments in relation to control where no treatment was added and the increment was more pronounced after 90 days of the growth of sunflower (Fig. 1). These results indicate that the vegetative growth of sunflower was much induced by the treatments specially SM, which might be due to its initial high content of organic matter and other nutrients (Table 1) rather than sulfur content. The leaf area of the sunflower also showed the similar trend as that of the plant height and dry matter production (Fig. 1). The maximum straw dry matter yield was recorded by the application of SM_{75}, followed by SM_{50} > MS_{75} treatments in both the soils. These treatments significantly ($p \leq 0.05$) varied among each other, suggesting that the application of SM at the rate of 50 kg ha^{-1} was more potential and effective than MS_{75} treatment for the growth of sunflower. The application of MS at 25 kg ha^{-1} was found to be significant for the most cases of growth parameters of sunflower but its higher rates (50, 75 kg ha^{-1}) were much effective (Fig. 1), indicate that the application of MS_{25} for this sulfur deficient soils was not enough but its higher rates were effective though the economic analysis of these rates are needed to consider for further study under field level. On the other hand, the application of SM even up to 75 kg ha^{-1}

Table 4: Effects of sulfidic materials (SM: kg ha^{-1}) and $MgSO_4$ (MS: kg ha^{-1}) as fertilizers for the growth and yield performance of sunflower grown on two sulfur deficient soils

Treatments No.	Denotation	Flower head Dia. (cm)	#IOC (%)	Seed/Head (Number)	Seed yield (g/plant)	#IOC (%)	1000-grain wt. (g)
Sirajgonj soil							
T_1	Control	9.6e†		220d	16.1e		50.2c
T_2	MS_{25}	10.2d	6.3	280c	19.2de	19	50.4c
T_3	MS_{50}	10.2d	6.3	276c	20.1d	25	66.5b
T_4	MS_{75}	13.5c	40.7	304bc	25.2c	56	69.8b
T_5	SM_{25}	14.3bc	49.0	293bc	21.2d	31	64.6bc
T_6	SM_{50}	16.4a	70.8	330b	30.3b	88	86.9ab
T_7	SM_{75}	17.3a	80.2	390a	43.2a	169	89.3a
LSD at 5% =		1.9		43	4.7		9.2
MS-IOC		41.0	---	38	57.0	---	334.0
SM-IOC		80.0	---	77	168.0	---	455.0
Gazipur soil							
T_8	Control	8.7c		190d	11.3d		39.2d
T_9	MS_{25}	9.6c	10.3	220d	16.4cd	45	44.3d
T_{10}	MS_{50}	10.0bc	14.9	233cd	19.3c	73	55.6c
T_{11}	MS_{75}	10.5bc	20.7	300b	22.3bc	100	64.3bc
T_{12}	SM_{25}	11.1b	27.6	260c	18.4c	64	60.4bc
T_{13}	SM_{50}	14.3ab	64.4	310b	22.4bc	100	63.2bc
T_{14}	SM_{75}	15.4a	77.0	355a	31.3a	182	81.9a
LSD at 5% =		1.7		38	3.3		8.5
MS-IOC		21.0	---	58	---	97	64.0
SM-IOC		77.0	---	87	---	178	109.0

#IOC = Increased over control. †In a column, means followed by a common letter(s) are not significantly different at 5% level

showed strong significant positive effects on the these growth parameters, suggesting that the application of SM was more effective than MS as sulfur fertilizer. Moreover, its higher doses also exerted higher response reflecting its high potential against MS as sulfur fertilizer. As expected, the lowest values for these plant characters were recorded in the control pots (T_1, T_8), where only basal application of N, P and K was performed. It is interesting to note that all the rates of SM and the higher rates of MS treatments significantly ($p \leq 0.05$) improved the growth parameters of sunflower compared with the control. Though, the treatments differed widely in their effects.

Seed yield and yield components of sunflower: The analyses of the data revealed that the average seed yield was 25% higher in the Gazipur soil than in the Sirajgonj soil (Table 4), which was attributed to the initial high CEC and the higher responses of sulfur in the Gazipur soil (Table 1). The sequence of effectiveness of SM and MS treatments on the seed yield (Table 4) was almost similar to and as significant ($p \leq 0.05$) as that of the effects observed on the straw dry matter production of Sunflower. The application of SM_{75} was found to be the most effective, followed by the $SM_{50} > MS_{75} \geq SM_{25}$ treatments for the seed yield and yield components of sunflower. The maximum seed yield (31.3 g/plant for the Gazipur soil and 43.2 for the Sirajgonj soil: Table 4) was recorded by the application of SM_{75}, followed by the SM_{50} (22.4, 30.3), MS_{75} (22.3, 25.2 g/plant) treatments in both soils. The application of SM was reported to be very effective due to the increase in the soil organic matter and release of some elements such as N, P, K, Mg and S into the growing media as well as micronutrients, which is very essential to plant growth. Irrespective of rates, the application of SM increased the seed yield by 168 and 178% IOC in the Sirajgonj soil and the Gazipur soil, respectively, whereas these increments were 57 and 97%, respectively by the equal amount of MS treatments (Table 4). The application of SM was also exerted significant effects to the increase in grain weight, flower head diameter and seed per head of sunflower but the application of MS was found somewhere significant and additive for these plant characters (Table 4). These effects were significantly more pronounced with the Gazipur soil (Table 5). Apart from soil conditions, the SM was found to be highly significant compared with the MS treatments (Table 5).

The above results indicate that the application of SM_{75} was the most effective to recover the deficiency of sulfur in sulfur deficient soils and increased the growth and yield of the sunflower. The results are in good agreement with the finding of some researchers. Of them, Pasricha and Aulakh (1991) in their twenty years of research on oil seed production in Punjab found that the availability of sulfur in the soils and the role of sulfur in sunflower were very satisfactory. Sreemannarayana and Raju (1994) studied with the effects of source and level of sulfur on yield and sulfur content of sunflower and also found satisfactory growth and yield responses of sunflower to sulfur application. Sreemannarayana *et al.*

Table 5: Comparison on selected yield performance of sunflower after harvesting at maturity as affected by sulfidic materials (SM: kg ha^{-1}) and $MgSO_4$ (MS: kg ha^{-1}) treatments in two sulfur deficient soils

	No. of seed per head			1000-grain weight (g)		
Treatments	Gazipur soil	Sirajgonj soil	MS and SM mean	Gazipur soil	Sirajgonj soil	MS and SM mean
Control	190e#	220d	205z	39.2e	50.2c	44.7z
$MgSO_4$			269y			58.5y
MS_{25}	220d	280cd		44.3de	50.4c	
MS_{50}	233cd	276cd		55.6c	66.5bc	
MS_{75}	300b	304bc		64.3b	69.8b	
Sulfidic materials			323x			74.4x
SM_{25}	260c	293c		60.4bc	64.6bc	
SM_{50}	310b	330b		63.2b	86.9ab	
SM_{75}	355a	390a		81.9a	89.3a	
Soil mean	267m	299n		58.2m	68.2n	
LSD at 5% level =			31			8.1

#In a column and the row of soil mean followed by a common letter(s) are not significantly different at 5% level

(1995) worked on the effects of sulfur on yield and quality of sunflower and concluded that the application of different sources of sulfur (gypsum, $MgSO_4$, $(NH_4)_2SO_4$ and elemental sulfur) at the rate of 0, 20, 40 and 60 kg ha^{-1} significantly increased both seed and stalk yields of sunflower with an increase in sulfur levels irrespective of sources of sulfur used. Khan *et al.* (2002) reported that the high organic matter (2-9%), total sulfur (3-7%) and micronutrients in the ASSs or SM deserve attention to use these soil materials for the reclamation of alkaline, calcareous or sulfur deficient soils and ASSs themselves. They also added that the high Mg and Al contents of the soils may be valuable for tea plants and nursery crops. But since the sulfide layers in acid sulfate soils can exert severe effects on surrounding ecosystems, immediate steps should be taken to consider these soils further.

CONCLUSIONS

The present study concludes that the application of sulfidic materials (SM) was increased (increase over control = IOC) the seed yield of sunflower by 168 and 178% IOC, while the equivalent amounts of $MgSO_4$ was increased the parameter by 57 and 97% IOC in the Sirajgonj and Gazipur soils, respectively. Moreover, the organic matter, available and total S contents in the soils were increased by 27 and 91%, 172 and 187% and 53 and 103% in the Sirajgonj and Gazipur soils, respectively irrespective of kinds and amounts of the treatments. The response of SM was strikingly pronounced till the final harvest at maturity of sunflower regardless of soil conditions and growth parameters, suggesting that the application of SM compared with $MgSO_4$ as a source of sulfur fertilizer was potentially more valuable for the improvement of fertility and productivity of sulfur deficient soils. The high organic matter (4%), available S (244 mM kg^{-1}) and total S (1656 mM kg^{-1}) and high Mg and other nutrient contents of the SM deserve attention to use these soil materials for the reclamation of relevant saline, alkaline, calcareous and sulfur deficient soils. The acid sulfate soils will also be reclaimed permanently by this process of removal of the SM from the soils. Since the SM in acid sulfate soils can exert severe effects on surrounding ecosystems, immediate steps should be taken to consider these soils further.

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REFERENCES

BARC (Bangladesh Agriculture Research Council), 1997. Fertilizer Recommendation Guide. Publ. BARC, Farm gate, Tejgaon, Dhaka Bangladesh.

Berry, L.S. and J. Schimidt, 2001. Measuring the impact of the health care sector on a local economy: Sunflower County, Mississipi. A Report Presented to the Mississipi State Department of Health, Regional Office, David Lightwine, October, 2001.

Kabir, S.M., 2005. Acid sulfate soil ecosystems and their sustainable management. Unpublished Ph.D Thesis, University of Dhaka, Bangladesh.

Khan, H.R., S. Rahman, M.S. Hussain and T. Adachi, 1994. Growth and yield response of rice to selected amendments in an acid sulfate soil. Soil Sci. Plant Nutr., 40: 231-242.

Khan, H.R. and T. Adachi, 1999. Effects of selected natural factors on soil pH and element dynamics studied in columns of pyretic sediments. Soil Sci. Plant Nutr., 45: 783-793.

Khan, H.R., M.M.A. Bhuiyan, S.M. Kabir, F. Ahmed, S.M.A. Syeed and H.P. Blume, 2002. The Assessment and Management of Acid Sulfate Soils in Bangladesh in Relation to Crop Production, Chapter 22. pp: 254-263. In: The Restoration and Management of Derelict Land: Modern Approaches. Wong, M.H. and A.D. Bradshaw (Eds.), World Scientific, www.worldscientific.com.

Khan, H.R., H.P. Blume, M.M.A. Bhuiyan and S.M. Kabir, 2005. Spatial and temporal patterns of acidification in acid sulfate soils and their environmental threats. A case study in Bangladesh. Presented in the International Conference on Environmental Process Engineering and its Related Sciences Held on 25-28th February 2005 in Penang, Malaysia.

Khan, H.R., M.M.A. Bhuiyan, S.M. Kabir, Y. Oki and T. Adachi, 2006. Effects of selected treatments on the production of rice in acid sulfate soils in a simulation study. Jap. J. Trop. Agric., 50: 109-115.

Klute, A., 1986. Methods of Soil Analysis. Agron. Series 9. Am. Soc. Agron., Publ. Madison, WI, USA.

Orndorff, Z. and W.L. Daniels, 2002. Delineation and management of sulfidic materials in Virginia highway corridors. Final Report to the Virginia Transportation Research Council, Charlottesville, Virginia, Sept. 2002, VTRC 03-CR3.

Pasricha, N.S. and M.S. Aulakh, 1991. Twenty years research and oilseed production in Punjab, India. Sulfur in agriculture Punjab Agricultural University, Lundhiana, India, 15: 17-23.

Sheeran, B., 2003. Virotec. International Ltd., www.virotec.com.

SRDI (Soil Resources Development Institute), 1999. Map of the nutrient status of sulfur and upazila land soil resource utilization guide.

Sreemannarayana, B. and A.S. Raju, 1994. Effect of source and level of sulfur on yield and sulfur content of plant of sunflower (*Helianthus annus*). Indian J. Agric. Sci., 63: 147-151.

Sreemannarayana, B., A.S. Raju and Satyanarayana, 1995. Effects of sulfur on yield and quality of sunflower. J. Maharashtra Agric. Univ., 20: 63-65.

Tonev, T.K., 2006. Agronomy characteristics of high yielding sunflower crop (Resume of research for habitation), Res. Commun. U.S.B Branch Dobrich, 8: 162-173.

Zaman, S.M.H., K. Rahman and M. Howlader, 1982. Simple lessons From Biometry. Publ. No. 54, Bangladesh Rice Research Institute, Gazipur, Bangladesh.