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EFFECT OF SULPHUR FERTILIZATION ON THE GROWTH AND YIELD OF GARLIC (*Allium sativum* L.)

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Abstract

The experiment was conducted for two consecutive *rabi* seasons of 2005-06 and 2006-07 at the Regional Agricultural Research Station (RARS), BARI, Jamalpur to find out an optimum dose of sulphur for yield maximization of garlic cv. Jamalpur local. There were six levels of sulphur viz., 0, 15, 30, 45, 60, and 75 kg/ha. A control treatment was in the experiment. The experiment was laid out in randomized complete block design with three replications. The fertilizer package $N_{150}P_{60}K_{120}Zn_4$ B_1 kg/ha was applied to each plot as blanket dose. Results revealed that most of the growth and yield parameters increased progressively with increasing rate of sulphur application. Bulb yield increased with successive increase in the level of sulphur up to 45 kg/ha and thereafter decreased. The highest bulb yield (7.05 t/ha in 2005-06 and 7.22 t/ha in 2006-07) was achieved at 45 kg S/ha and the control treatment receiving no fertilizer had the lowest yield (3.21 t/ha in 2005-06 in and 3.26 t/ha in 2006-07). The yield benefit for 45 kg sulphur per ha was 34.2% in 2005-06 and 40.0% in 2006-07 over no sulphur. Sulphur at 45 kg/ha produced 54.5% and 54.9% higher yield over control treatment in both the years. The optimum and economic dose of sulphur for the yield of garlic were 44.0 and 43.6 kg/ha, respectively.

Keywords: Sulphur, garlic growth, and bulb yield

Introduction

Sulphur is the fourth major plant nutrient after nitrogen, phosphorus, and potassium. It is essential for the synthesis of amino acids like cystine, cysteine, and methionine, a component of vitamin A and activates certain enzyme systems in plants (Havlin *et al.*, 2004). Continuous removal of S from soils through plant uptake has led to widespread S deficiency and affected soil S budget (Aulakh, 2003) all over the world. Sulphur deficiency in Bangladesh soils is becoming widespread and acute. Use of high analysis fertilizers, such as urea, TSP, MoP, and ammonium phosphate, cultivation of modern varieties, increasing cropping intensities and limited application of organic manure have all contributed to the intensification of the S deficiency problem in Bangladesh soils (Islam, 2008). Garlic (*Allium sativum* L.) is the second most important spice crops next to onion (Bose and Som, 1990). It is taken for curing many human diseases. (Augusti, 1997; 2000; Durak *et al.*, 2004; and Pitman, 2008).

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At present, 1.02 million tons garlic bulbs are produced in Bangladesh against the requirement of 2.19 million tons (BBS, 2006). The average yield of garlic in our country is 3.82 t/ha which is very low (BBS, 2006) compared to 11.07 t/ha produced by garlic producing countries of the world. Lower yield of garlic in Bangladesh is mainly due to degradation of soil fertility, imbalanced fertilization, and lack of proper crop management practices. Sulphur application in garlic enhances the uptake of N, P, K, and Ca by the crop (Hossain, 1997). Report is available that apart from NPK fertilizer, sulphur can play a vital role in increasing the yield of garlic (Ahmed *et al.*, 1988). Plant height, number of leaves/plant, cloves/bulb, diameter and weight of bulb and bulb yield increased with the application of sulphur (Nasrin *et al.*, 2007). Alam (1995) stated that sulphur played an appreciable role in increasing yield by increasing the number of leaves/plant, plant height, number of cloves/bulb and fresh and dry weight of bulb. Combined effect of sulphur and boron on the emergence of seedling, plant height, bulb yield, and yield contributing characters was found significant (Islam and Huq, 1999). The present investigation was, therefore, undertaken to see the impact of sulphur applicantion on growth and yield of garlic crop.

Materials and Method

The experiment was conducted at the research field of Regional Agricultural Research Station (RARS) Jamalpur in two consecutive *rabi* seasons of 2005-06 and 2006-07. The objective of the study was to find out an optimum dose of sulphur for garlic production. The soil of the experimental field was silt loam in texture belonging to Sonatola Soil Series under the AEZ 9: Old Brahmaputra Floodplain (FAO, 1971). Organic matter content of the soil was low. The soil was acidic in nature. Total N and exchangeable K status of the soil were also low. The available phosphorus, sulphur, boron, and zinc were either at par or below the critical level (Table 1). Six levels of sulphur viz., 0, 15, 30, 45, 60, and 75 kg/ha were used in the experiment. There was a control treatment in the study. The fertilizer package $N_{150}P_{60}K_{120}Zn_4 B_1$ kg/ha was applied to each plot as blanket dose. The experiment was carried out in randomized complete design with three replications. The unit plot size was 2.0 m x 1.5 m. Seeds of garlic (cv. BARI Rasun-1) were sown on first week of November at spacing of 15 cm and 10 cm. The crop was harvested on 28 March 2006 and 30 March 2007 when the plants attained maturity and showing drying up of most of the leaves and bending over. Harvesting was done with the help of a Nirani. Care was taken to avoid any kind of bulb injury during lifting. Intercultural operations were done as and whenever required. Data on plant growth, yield parameters, and bulb yield were taken and analyzed through MS STAT programme. The DMRT test was used for mean separations of the studied parameters.

Table 1. Nutrient status of the initial soil.

Soil parameters	Values
pH (1:2.5 Soil-water)	5.80
Bulk density (g/cm)	1.43
Exchangeable K (c mol/kg)	0.12
Exchangeable Ca (c mol/kg)	3.60
Exchangeable Mg (c mol/kg)	1.05
Organic matter (%)	1.07
Total N (%)	0.06
Available P (mg/kg)	14.5
Available S (mg/kg)	13.6
Available Zn (mg/kg)	1.14
Available B (mg/kg)	0.18

Results and Discussion

Plant height

Sulphur application showed a significant variation in plant height at different days after planting except at 30 DAP (Table 2). Plant height increased gradually with increasing the levels of sulphur up to 45 kg/ha beyond which it decreased. The tallest plants (71.5 cm) was recorded in plot fertilized with 45 kg S/ha, which was statistically similar to that recorded in 30 kg S/ha (70.8 cm). The shortest plants (44.3 cm) were found in control plots. Plant height recorded in 2006-07 across the treatments followed the pattern similar to those observed in 2005-06. Increased plant height with increased sulphur fertilization was also reported by Vachhani and Patel (1993); Jalil (1998) and Alam (1995).

Number of leaves/plant

The effect of sulphur on the production of leaves was found to be significant at different DAP (Table 2). At 110 DAP, the number of leaves/plant was maximum (9.0) in treatment with 45 kg S/ha, while the minimum number (6.67) was recorded in plot where no fertilizer was applied. In 2006-07, there was no significant variation in number of leaves/plant at 50, 70, and 90 DAP, whereas at 30 and 110 DAP as well as at harvest, it differed significantly. The maximum number of leaves/plant (8.23) was recorded in 45 kg S/ha, which was comparable to those recorded in other sulphur treatments except sulphur control plot and the minimum (6.80) was observed in plants with no fertilizers.

Table 2. Effects of sulphur (S) on plant height at 20-day interval.

Sulphur (kg/ha)	Plant height at different DAP (cm)									
	2005-06					2006-07				
	30	50	70	90	110	30	50	70	90	110
0	22.2 ab	32.3 c	37.5 b	50.4 c	56.4 d	24.1 ab	33.8 a	39.1 bc	51.1 c	57.4 e
15	22.6 a	35.2 ab	40.9 b	56.1 b	63.1 c	24.4 ab	33.9 a	39.9 ab	56.7 b	64.8 cd
30	23.2 a	36.0 a	41.3 b	60.5 ab	70.8 a	24.4 ab	34.5 a	43.3 ab	61.5a	69.3 ab
45	22.9 a	35.4 ab	46.3 a	62.7 a	71.5 a	23.7 ab	36.4 a	44.3 a	63.7a	71.5 a
60	23.2 a	33.9 b	41.9 b	56.4 b	66.9 b	24.8 ab	34.5 a	41.9 ab	61.9a	66.4 bc
75	22.6 a	34.4 ab	39.9 b	57.0 b	66.4 b	26.2 a	37.0 a	43.1 ab	62.0 a	61.8 d
Control (No fert.)	20.7 b	28.1 d	32.3 c	40.2 d	44.3 d	21.5 b	29.7 b	35.3 c	44.7 d	43.9 f
CV (%)	3.62	2.64	6.11	5.40	4.28	6.89	5.92	5.76	8.68	3.87

Figures in a column having same letters do not differ significantly at 5% level of probability, Every treatment received N_{150} P_{60} K_{120} Zn_4 B_1 kg/ha

Table 3. Effects of sulphur on number of leaves/plant at regular 20-day interval.

Sulphur (kg/ha)	Number of leaves/plant at different DAP									
	2005-06					2006-07				
	30	50	70	90	110	30	50	70	90	110
0	4.80 ab	5.40 bc	6.40 ab	7.00 b	7.73 b	4.17 ab	5.37	6.42	6.73	7.50 b
15	4.90 a	5.73 ab	6.93 ab	7.17 ab	8.47 a	4.23 ab	5.47	6.47	6.80	7.83 ab
30	5.00 a	5.87 ab	6.23 ab	7.20 ab	8.80 a	4.20 ab	5.70	6.40	6.80	8.07 ab
45	4.80 ab	5.87 ab	7.10 a	7.47 ab	9.00 a	4.17 ab	5.83	6.17	6.47	8.23 a
60	4.80 ab	5.57 ab	6.80 ab	7.33 ab	8.87 a	4.23 ab	5.73	6.20	6.87	8.20 a
75	4.90 a	6.10 a	6.70 ab	7.53 a	8.73 a	4.27 a	5.70	6.43	6.83	7.93 ab
Control (No fert.)	4.40 b	4.90 c	6.00 b	6.27 c	6.67 c	4.07 b	5.37	5.87	6.27	6.80 c
CV(%)	4.84	5.40	0.95	0.47	4.94	2.41	5.28	7.07	5.27	4.24

Figures in a column having same letters do not differ significantly at 5% level of probability

Every treatment received $N_{150} P_{60} K_{120} Zn_4 B_1$ kg/ha

Dry weight of leaves/plant

Leaf dry weight/plant was affected significantly by sulphur fertilization at maximum growth stage of plant (Table 4). The highest leaf weight (2.07g in 2005-06 and 2.20 g in 2006-07) was recorded in 45 kg S/ha, which was significantly higher than the weights recorded in rest of the treatments. The plants grown without sulphur produced the lowest dry leaf weight (1.38 g in 2005-06 and 1.32 g in 2006-07).

Dry weight of plant

Sulphur had significant effects on dry plant weight at maximum growth stage (Table 4). It increased progressively with increasing the levels of sulphur from 0 to 45 kg/ha. The maximum plant dry weight (4.20 g) was obtained from 45 kg S/ha and the minimum (1.73 g/plant) was recorded in control treatment. This might be due to maximum vegetative growth which enhanced maximum photosynthesis and accumulation of more dry matter in plants. The increase in dry plant weight due to sulphur fertilization indicates a positive role of sulphur on vegetative growth of plant.

Table 4. Effect of different levels of sulphur on dry weight of leaves, root and single plant weight at the maximum stage of growth.

Sulphur (kg/ha)	Dry wt of leaves/plant (g)		Dry wt of roots/plant (g)		Dry wt of single plant (g)
	2005-06	2006-07	2005-06	2006-07	2006-07
0	1. 38 d	1.32 de	0.16 b	0.16 b	2.77 d
15	1. 56 c	1.67 bc	0.18 ab	0.20 a	3.17 c
30	1. 84 b	1.80 b	0.20 a	0.20 a	3.83 b
45	2. 07 a	2.20 a	0.21 a	0.22 a	4.20 a
60	1. 76 b	1.55 a	0.21 a	0.22 a	3.10 a
75	1. 40 d	1.44 bcd	0.20 a	0.20 a	2.88 d
Control (No fert.)	1. 04 e	1.08 cd	0.10 c	0.11 c	1.73 e
CV (%)	4. 95	8.81 e	10.79	11.55	3.70

Figure in a column having same letter do not differ significantly at 5% level of probability.

Every treatment received N_{150} P_{60} K_{120} Zn_4 kg B_1 /ha as a blanket dose.

Dry weight of root/plant

Dry weight of roots/plant at harvest significantly affected by sulphur application (Table 4). The maximum root dry weight/plant (0.21 g in 2005-06 and 0.22 g in 2006-07) was recorded in the same dose of sulphur fertilizer.

Number of cloves/bulb

Application of sulphur significantly increased yield attributes of garlic over control in both the years. The maximum number of cloves/bulb (19.2 in 2005-06 and 22.1 in 2006-07) was recorded at 45 kg S/ha, the minimum values (13.1 in 2005-06 and 16.9 in 2006-07) were recorded in plants where no fertilizers was applied (Table 5).

Bulb length

Significant variation in bulb length was observed due to application of sulphur (Table 5). The maximum length of bulb at harvest (2.95 and 3.06 cm) was recorded at 45 kg S/ha. Results revealed that bulb length showed a decreasing trend with the increasing levels of S after 45 kg/ha. The minimum length of bulb (1.96 cm and 2.02 cm) was observed in plants with no application of fertilizers.

Diameter of bulb

Sulphur application has created significant impact on bulb diameter of garlic (Table 5). The highest bulb diameter (3.19 cm in 2005-06 and 3.57 cm in 2006-

07) was recorded in treatment receiving 45 kg S/ha, while the lowest (2.24 cm in 2005-06 and 2.31 cm in 2006-07) was observed in control treatment. Sulphur application at 45 kg S/ha favoured plant growth and development thus producing large bulbs. Nasrin *et al.* (2008) also found large size bulbs with higher doses of sulphur (40 to 60 kg/ha).

Table 5. Effect of different levels of sulphur on yield components of garlic.

Sulphur (kg/ha)	Bulb length (cm)		Bulb diameter (cm)		Fresh wt of single bulb (g)		No. of cloves/bulb	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
0	2.38 b	2.46 c	2.53 d	2.58 cd	11.7 b	12.2 c	16.8 b	19.2
15	2.68 a	2.76 b	2.79 cd	2.93 bc	12.3 b	14.4 ab	18.6 a	18.9
30	2.82 a	2.90 ab	3.13 ab	3.25 ab	14.1 a	15.9 a	18.4 a	18.9
45	2.95 a	3.06 a	3.19 a	3.57 a	14.3 a	16.0 a	19.2 a	22.1
60	2.73 a	2.87 ab	2.87 bc	3.06 ab	14.0 a	13.9 abc	16.1 b	16.9
75	2.83 a	2.78 ab	2.80 cd	2.94 bc	13.7 a	13.0 bc	18.6 a	18.8
Control (No fert.)	1.96 c	2.02 d	2.24 e	2.31 d	8.31 c	8.93 d	13.1 c	16.9
CV (%)	6.18	5.50	5.28	6.65	3.80	8.30	5.11	14.8

Figures in a column having same letter do not differ significantly at 5% level of probability.

Every treatment received N_{150} P_{60} K_{160} Zn_4 kg/ha as a blanket dose.

Weight of bulb

Significant variations in fresh weight of bulb at harvest was observed due to application of different doses of sulphur (Table 5). The maximum weight of fresh bulb (14.3 g in 2005-06 and 16.0 g in 2006-07) was obtained at 45 kg S/ha. This might be due to adequate nutrient supply which favoured in enlaraging the bulb, this increased the weight of bulb. The result is in conformity with the findings of Nasiruddin *et al.* (1993) who reported that application of both potassium and sulphur either individually or in combined increased plant height, leaf production, bulb diameter, bulb weight as well as the bulb yield. The minimum weight of bulb (8.31 g and 8.93 g) was observed in the control treatment.

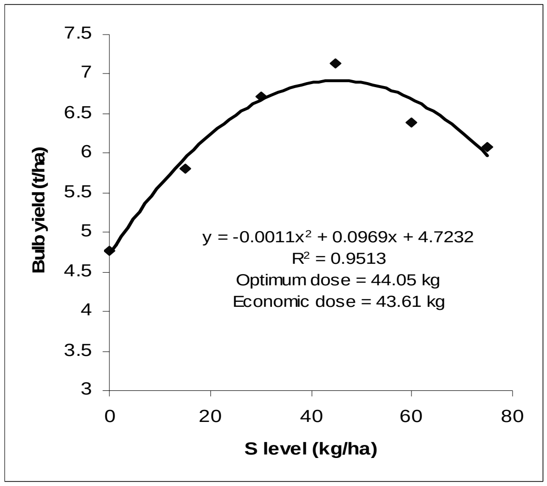

Figure 1.Relationship between sulphur levels and bulb yield

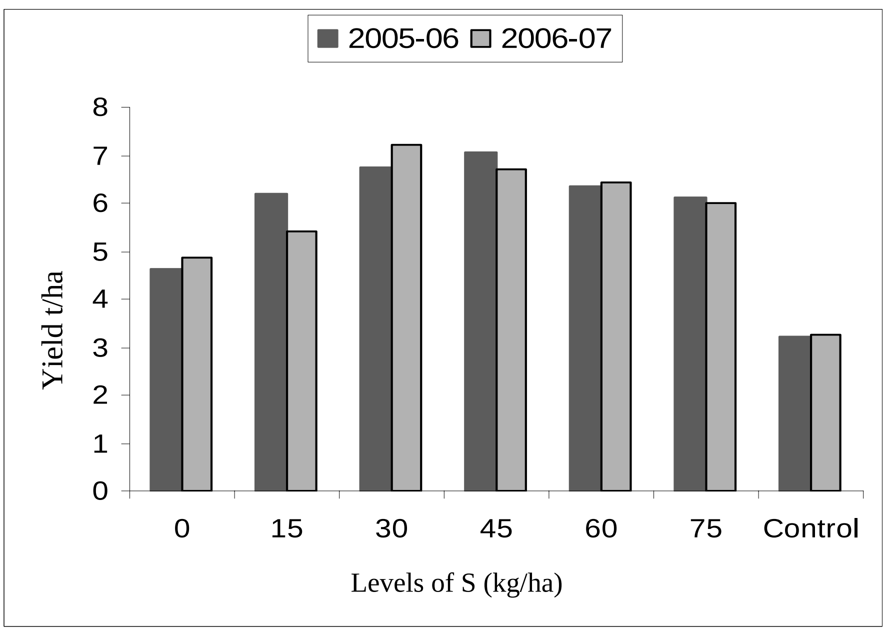

Figure 2. Effect of different levels of S on the yield of garlic

Bulb yield

Bulb yield of garlic was greatly influenced by sulphur fertilization (Fig. 2). The highest bulb yield (7.05 t/ha in 2005-06 and 7.22 t/ha in 2006-07) was achieved at 45 kg S/ha and the control treatment receiving no fertilizer had the lowest yield (3.21 t/ha in 2005-06 and 3.26 t/ha in 2006-07). The maximum bulb yield obtained at 45 kg S/ha was due to tallest plants, maximum number of leaves/plant, maximum cloves/bulb, and heaviest bulbs produced in the treatment that had led to produce significantly higher yield. The yield benefit for 45 kg sulphur/ha was 34.2% in 2005-06 and 40.0% in 2006-07 over no sulphur. Again it was found that 45 kg S/ha produced 54.5% and 54.9% higher yield in both the years, respectively, over control treatment. The result is in conformity with the findings of Anwar *et al.* (1996) and Nasrin *et al.* (2008). It is important to note that bulb yield beyond 45 kg/ha sulphur application decreased with increasing levels of sulphur. The result is in agreement with the findings of Alam (1995). Bulb yield increased with successive increase in the level of sulphur up to 45 kg/ha and thereafter decreased. This might be an imbalance or antagonistic effect on plant nutrition that resulted in the reduction of yield. There was a quantum jump in yield due to sulphur application suggesting that the soil was deficient in sulphur that resulted in a big yield differences with 30 and 45 kg S/ha. The relationship between the sulphur rates and the yields were explained by polynomial models ($Y = a + bx + cx^2$) (Fig. 1). The value of $R^2 = 0.9513$ indicates that different S levels can attribute to 95% of the variation in yield. The optimum and economic yield of garlic estimated from the regression equation were 44.0 and 43.6 kg/ha, respectively. Above the said optimum dose there is a possibility of loosing certain amount yield.

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