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Effect of sulphur on growth, yield and yield attributes in onion (*Allium cepa* L.)

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Abstract

This experiment was conducted to study the effect of different doses of sulphur on growth and yield performances of onion. The experiment comprised of five levels of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}) and was laid out in RCBD design with four replications and other fertilizers were applied according to recommended doses. Individual bulb weight, dry weight of root, dry weight of bulb, dry weight of shoot, dry weight of leaf, total dry matter (TDM), leaf area index (LAI), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR**)**, individual bulb weight, bulb yield of onion and sulphur content were increased significantly with the application of sulphur fertilizer. The maximum sulphur content (0.49%) of onion bulb was observed in 40 kg S ha^{-1} followed by 20 kg S ha^{-1}(0.45 %), 60 (0.45%) and 80 kg S ha^{-1} (0.44%) at average of 45 and 85 days after transplanting. However, number of splitted bulb, bulb diameter, neck diameter, and neck bulb ratio were not significantly affected by different doses of sulphur application. Application of 40 kg S ha^{-1} resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulphur. The present study clearly indicates that sulphur at 40 kg ha^{-1} may be recommended for better growth and yield of onion under silty loam in texture having pH around 6.5.

Keywords: Sulphur; Dry matter; growth; yield and; onion.

Abbreviations: RCBD-Randomized Complete Block Design; TDM-Total Dry Matter; LAI-Leaf Area Index; AGR-Absolute Growth Rate; RGR-Relative Growth Rate; NAR-Net Assimilation Rate, FAO-Food and Agriculture Organization of the United Nations, BBS-Bangladesh Bureau of Statistics; DAT-Days After Transplanting; AEZ-Agro Ecological Zone; UNDP-United Nations Development Programme; DMRT-Duncan's Multiple Range Test

Introduction

Onion (*Allium cepa* L.) belonging to the family Alliaceae is widely used as most important crop among the vegetables and spices. There are more than 500 species under the genus *Allium*; of these most of them are bulbous plants. It has been cultivated for 5000 years or more and does not exist as wild species (Brewster, 1994) of the 15 vegetable and spice crops listed by FAO. It is used in almost all food preparations and is an integral part of Bangladesh diet (Hossain and Islam, 1994). Among all spice crops, onion has great significance for its diversified use. It contains vit-A, vit-C, iron and calcium. Onion also reduces blood sugar. The origin of onion is thought to be Iran, Pakistan and the mountainous regions to north of these countries (Purseglove, 1972). The leading onion growing countries of the world are the Netherlands, Korea, Israel, Japan, Turkey, Syria, Egypt, USA, Lebanon and India (FAO, 1998). In Bangladesh, it is commercially cultivated in the greater districts of Faridpur, Rajshahi, Jessore, Pabna and Kushtia (BBS, 2004). It is grown extensively during winter season in Bangladesh, occupying the first position both in area and production (BBS, 2006). It is grown more or less in all the districts of the country; however, the average yield is 5.24 t ha^{-1}, which is very low as compared to many other onion producing countries of the world. The average world production is about 15 t ha^{-1} (FAO, 2003). On an average, the total annual requirement of onion in Bangladesh stands at 500 thousand metric tons whereas, the total production is only 127 thousand metric tons and thereby, there is a shortage of 373 thousand metric tons per annum. To meet this shortage, Bangladesh has to import onion every year at the cost of its hard earned foreign currency (Hussain and Islam, 1994). Onion is a sulphur loving plant and is required much for proper growth and yield of onion (Kumar and Singh, 1995). Sulphur has been found not only to increase the bulb yield of onion but also improves its quality, especially pungency and flavors (Jaggi and Dixit, 1999). Bell (1981) also reported sulphur containing secondary compounds was not only of importance for nutritive value and flavors, but also for resistance against pests and diseases. The yield potential of onion has not been exploited fully as the sulphur fertilizer is used in very low quantity instead of its very high requirement. Faridpuri Bhati is an important indigenous cultivar of onion which is grown widely throughout the country. But its method of production, including the application of manures and fertilizers has not been standardized yet. It is possible that judicious application of nutrients will increase the yield of local cultivars significantly. Sulphur is essential for building up sulphur containing amino acids in plant cells, particularly in the early

Table 1. Effect of different doses of sulphur on yield contributing characters of onion.

Level of S (kg ha^{-1})	Fresh weight of onion (g)	Dry weight of onion (g)	Bulb diameter (cm)	Neck diameter (cm)	Neck Bulb	Number of splitted bulb
0	21.71d	3.26d	3.72	1.25	0.34	6.25
20	27.17b	4.08b	3.87	1.29	0.36	9.25
40	31.20a	4.68a	3.97	1.41	0.32	7.75
60	27.63b	4.14b	3.90	1.33	0.34	11.25
80	23.33c	3.50c	3.82	1.31	0.34	10.00
LS	**	**	NS	NS	NS	NS
$LSD_{(0.05)}$	3.76	0.52	-	-	-	-
CV (%)	3.11	3.11	3.54	7.27	7.43	25.01

Values in a column containing same letter(s) do not differ significantly as per DMRT; LS-Level of significant

stage of plant growth. In recent years, sulphur is receiving more attention throughout the world. Sulphur is essential for building up sulphur containing amino acids and also for a good vegetative growth and bulb development in onion (Anwar et al., 2001). However, most of Bangladesh soils are deficient in available sulphur which roughly covers 44% of the total cropped area (Hossain, 1990). This deficiency is becoming acute over time due to extensive use of sulphur free fertilizer, intensive crop production and poor sulphur status of soils. Non-application of sulphur in sulphur deficient soils has often resulted in low yield of onion. Sulphur deficient plants also had poor utilization of macro and micronutrients (Kumar and Singh, 1994) and significantly lower total solids in onion bulbs at maturity (Kumar and Singh, 1992). The highest yield of onion and the maximum uptake of N and S were recorded by the combined application of 120 kg N and 40 kg S ha^{-1} with a blanket dose of 90 kg P2O5, 90 kg K2O, 5 kg Zn ha^{-1} and 5 t ha^{-1} cowdung (Nasreen et al., 2007). The highest bulb yields (19.75 and 19.88 t ha^{-1}) were obtained from sulphur levels between 60 and 75 kg ha^{-1}in two consecutive years (Ullah et al., 2008). As such sulphur is a key nutrient in onion production; therefore, lack of its optimum supply in different plant parts limits the crop growth at any stage, resulting in yield reduction. The present research work was undertaken to investigate the effect of sulphur fertilization on growth, yield and yield attributes in onion.

Results

The dry weight of root, bulb, stem, leaf in onion was significantly differed due to the application of different doses of sulphur (Figs. 1-4).

Effect of sulphur fertilization on dry weight of root, bulb, stem and leaf

For the dry weight of root, trend was rapidly increased up to 75 DAT and after that it increased slowly. At 85 DAT the highest leaf dry weight of root $plant^{-1}$ (0.54 g) was recorded by the application of 40 kg S ha^{-1} and the minimum (0.29g) was recorded where no sulphur fertilizer was added (Fig 1.). At 85 DAT the highest dry weight of bulb (9.98 g) was found in the plants grown with 40 kg S ha^{-1} and the lowest (5.06 g) at 0 Kg S ha^{-1}. This result is agreed with the findings of Jaggi (2004). Again at 85 DAT the highest dry weight of bulb (3.17 g) was found in the plants grown with 40 kg S ha^{-1} and the lowest (1.64 g) in 0 kg S ha^{-1}, which was statistically similar with 80 kg S ha^{-1} (Fig. 2). There was a significant effect of sulphur on dry weight of stem at 45, 55, 60, 75 and 85 DAT. There was an increasing trend observed in dry weight of stem per plant in respect of increasing days after transplanting (Fig. 3). At 85 DAT, the highest dry weight of bulb (3.17 g) was found in the plants with 40 kg S ha^{-1} and the lowest

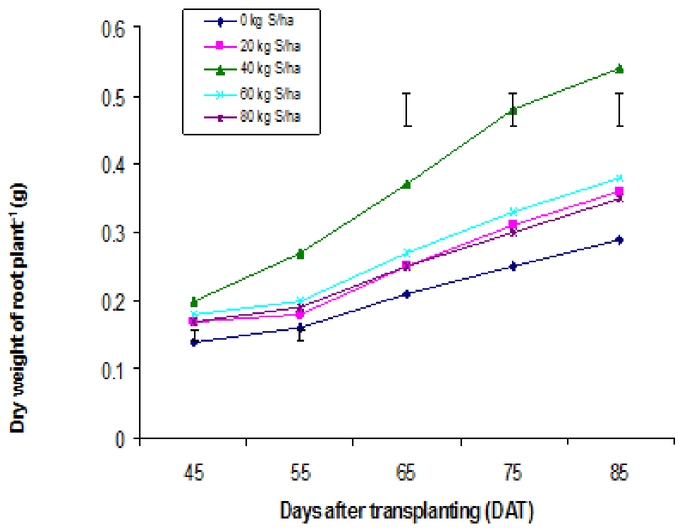

Fig 1. Effect of different doses of sulphur on dry weight of root at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

(1.64 g) was found in 0 kg S ha^{-1} which was statistically similar with 80 kg S ha^{-1}. The dry weight of leaf was significantly higher at 40 kg S ha^{-1} over other doses. On the other hand, control (no sulphur added) had the lowest leaf dry weight in all DATs. Numerically, the highest dry weight of leaf (4.25 g) was measured at 40 kg S ha^{-1} and lowest (1.96 g) in 0 kg S ha^{-1} at 75 DAT (Fig. 4).

Effect of sulphur fertilization on total dry matter production

Total dry matter production of a crop is dependent on the size of the photosynthetic system and the length of growth period, during which photosynthesis continues. The total dry matter increased up to 40 kg S ha^{-1} and then decreased further at higher levels of S (60 and 80 kg ha^{-1}) application. It was observed that TDM increased progressively with the advancement of time. At 85 DAT, the highest TDM (16.92 g) was found in the plants grown with 40 kg S ha^{-1} and the lowest (9.50 g) was found in application of 0 kg S ha^{-1} (Fig. 5).

Effect of sulphur doses on leaf area index (LAI)

The effect of different doses of sulphur was significant on leaf area index at different days after transplanting. Result revealed that leaf area index rapidly increased untill 65 DAT and it increased slowly up to 75 DAT followed by a sharp decline because of leaf shedding (Fig. 6). The leaf area production by 40 kg S ha^{-1} was significantly higher over

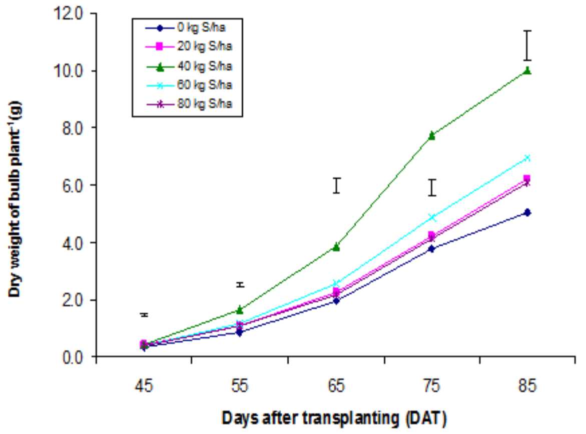

Fig 2. Effect of different doses of sulphur on dry weight of bulb at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

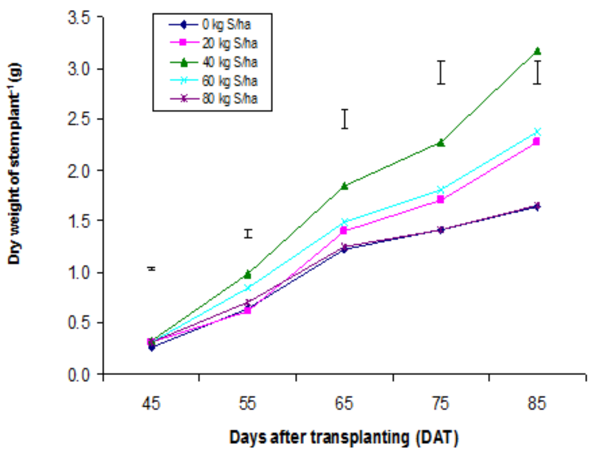

Fig 3. Effect of different doses of sulphur on dry weight of stem at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

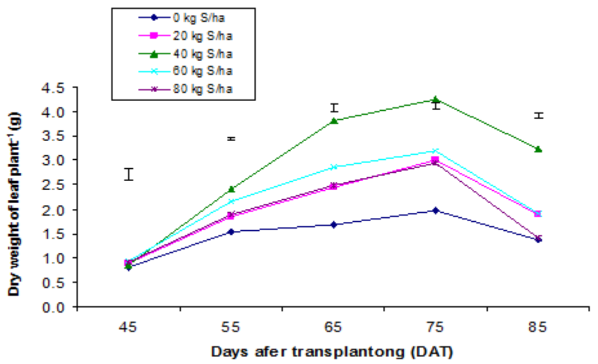

Fig 4. Effect of different doses of sulphur on dry weight of leaf at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

other doses. On the other hand, control (no sulphur added) had the lowest leaf area at all DAT. Numerically, the highest leaf area index (0.77) was measured in application of 40 kg S ha^{-1} and lowest (0.65) in application of 0 kg S ha^{-1} at 75 DAT (Fig. 6). At 85 DAT, leaf area index was declined due to shedding of leaf.

Effect of sulphur doses on absolute growth rate (AGR) and relative growth rate (RGR)

Absolute growth rate (AGR) is the increase dry matter unit^{-1} of time plant^{-1}and it represents the efficiency of a plant as producer of new materials. The variation in AGR among the different levels of sulphur application was assessed from 45 to 85 DAT and the results are plotted in Fig. 7. It was observed that there existed a positive relationship between AGR and plant age until 65 to 75 DAT, after that the relationship was inverse. The effect of different levels of sulphur on AGR was found significant at all growth stages. The AGR showed the highest value at 65 to 75 DAT and continued to decline till 75 to 85 DAT. Sulphur significantly stimulated absolute growth rate in onion at 40 kg ha^{-1} in all growth period except 75 to 85 DAT at the present study (Fig. 7). The variation in RGR among the different levels of sulphur application was assessed from 45 DAT to 85 DAT and the results are plotted in Fig. 8. It was observed that there is an inverse relationship between RGR and plant age till 75 to 85 DAT. There was a significant variation observed in different level of sulphur in RGR at all growth stages except 65 to 75 DAT. Sulphur significantly stimulated relative growth rate in onion at 40 kg ha^{-1} in all growth period except 75 to 85 DAT at the present study (Fig. 8).

Effect of sulphur doses net assimilation rate (NAR)

The net assimilation rate (NAR) derived from five different doses of sulphur application was determined from 45 to 85 DAT. Results revealed that NAR in all doses of sulphur was significantly different at all growth stages. The highest value of NAR was observed during 45 to 55 DAT and; thereafter, it decreased with the progress in plant maturity (Fig. 9). The sulphur dose at 40 kg ha^{-1} produced higher NAR than the other doses. In contrast, the control plants maintained the lowest NAR over its growth period.

Effect of different doses of sulphur on yield, yield contributing characters and sulphur content of onion

Different doses of sulphur application had a significant variation on fresh and dry weight of individual onion. The maximum fresh weight (31.20 g) was observed with the application of 40 kg S ha^{-1} followed by 20 and 60 kg S ha^{-1}. The maximum dry weight (4.68 g) was observed where land was fertilized with 40 kg S ha^{-1} followed by 20 and 60 kg S ha^{-1} with same statistical rank (Table 1). Control treatment showed the minimum fresh and dry weight. The highest bulb diameter (3.97 cm) was observed with 40 kg S ha^{-1}. The highest neck diameter (1.41 cm) was observed with 40 kg S ha^{-1} and the highest neck bulb ratio (0.32) was observed with 40 kg S ha^{-1}. On the other hand, the highest number of split bulb was counted where 60 kg S ha^{-1} was added and the control showed the lowest value. A response curve on the effect of different doses of sulphur on yield of onion was constructed at final harvest. The sulphur dose at 40 kg ha^{-1} produced significantly highest yield and subsequently yield was reduced at 60 and 80 kg ha^{-1} (Fig. 10). Different doses of sulphur application had a significant variation on sulphur

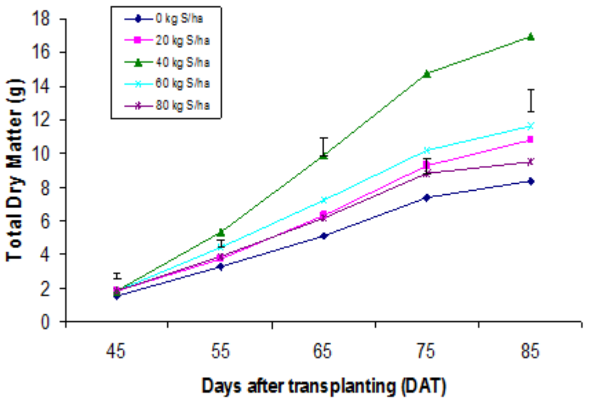

Fig 5. Effect of different doses of sulphur on total dry matter per plant at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

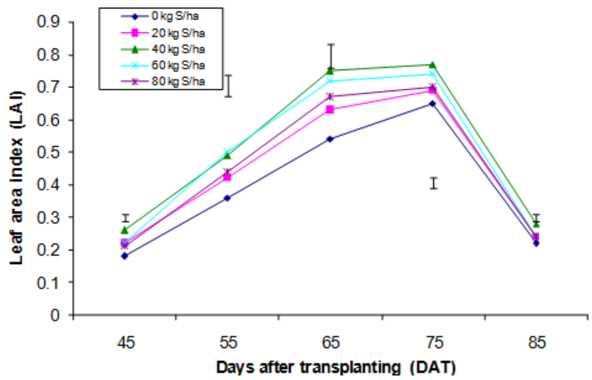

Fig 6. Effect of different doses of sulphur on leaf area index at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

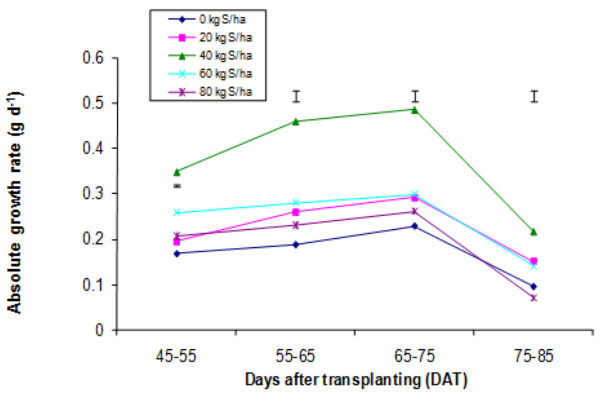

Fig 7. Effect of different doses of sulphur on absolute growth rate at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

content in bulb of onion. The maximum S content of onion bulb was observed in 40 kg S ha^{-1} followed by 20 kg S ha^{-1}, 60 and 80 kg S ha^{-1} at 45 and 85 DAT (Fig.11 and 12). Zero (0) kg S ha^{-1} showed the minimum sulphur uptake.

Discussion

The dry weight of root, bulb, stem, leaf, leaf area index, absolute growth rate, relative growth rate, net assimilation rate decreased when dose was increased after after 40 kg S in onion. These results corroborated with studies of Nasreen et al. (2007) and Smriti et al. (2002). The total dry matter increased up to 40 kg S ha^{-1} and then it decreased further at higher levels of S (60 and 80 kg ha^{-1}) application. This result is agreed with the findings of Jaggi (2004). The highest total dry matter was found in the plants grown with 40 kg S ha^{-1} and the lowest in application of 0 kg S ha^{-1}. The highest total dry matter obtained from 45 kg S ha^{-1} for onion was reported by Nasreen et al. (2003). Sulphur significantly stimulated absolute growth rate in onion at 40 kg ha^{-1} in all growth periods except 75 to 85 days after transplanting at the present study. Relative growth rate was the highest at early growth stage and decreased at later stage of crops. Nasreen et al. (2003) obtained growth rate values which increased progressively over time (reaching peak) at 60 to 75 days after transplanting and; thereafter, declined sharply till 105 days after transplanting. The maximum dry weight of bulb was found where land was fertilized with 40 kg S ha^{-1} followed by 20 and 60 kg S ha^{-1}. Jaggi (2005) observed the significant increase of dry weight of bulb with 30 kgha^{-1}S. Meena and Singh (1998) showed that S fertilization significantly enhanced the dry weight of onion tops and bulbs. On the other hand, the effect of different doses of sulphur application had no significant variation on bulb diameter, neck diameter, neck bulb ratio, number of splitted bulb of onion. The highest bulb diameter (3.97 cm) was observed with 40 kg S ha^{-1}. Nasreen et al. (2007) obtained the same result. In our results, the sulphur dose at 40 kg ha^{-1} produced the highest yield of onion. The highest yield was also reported by Nasreen et al. (2003) and Nasreen and Huq (2005) at 45 kg S ha^{-1} while Smriti et al. (2002) was obtained from 40 kg S ha^{-1}. Sulphur content in onion was the highest at 40 kg S ha^{-1} and decreased at 60 and 80 kg S ha^{-1}. Sulphur fertilizer might have promoted the availability of native soil S as reflected by their uptake. Similar opinion was reported by Nasreen et al. (2007).

Materials and methods

Experimental site and soil analysis

The experiment was conducted at the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University, during the period of January to April 2008. The experimental site was medium high land belonging to the Sonatola series of Old Brahamaputra Flood Plain Soil (AEZ-9), Bangladesh (UNDP, 1988). The soil of the experimental plot was silty loam in texture, having pH around 6.5. The soil samples were air-dried, ground, and sieved with 1-mm (20-mesh) sieve. The composite sample was stored in a clean polyethylene bag for chemical analysis. Chemical properties of the experimental soil were as follows: Organic matter content (%) 1.63; Total N (%) 0.13 (low), Available P (ppm) 7.61 (Medium), Available S (ppm) 9.03 (low), Exchangeable K (me/100 g soil) 0.14 (low).

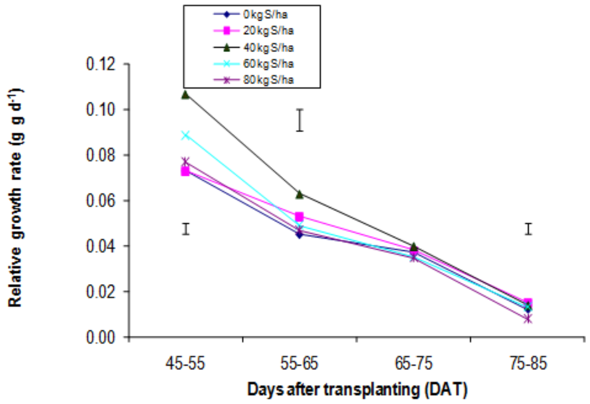

Fig 8. Effect of different doses of sulphur on relative growth rate at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

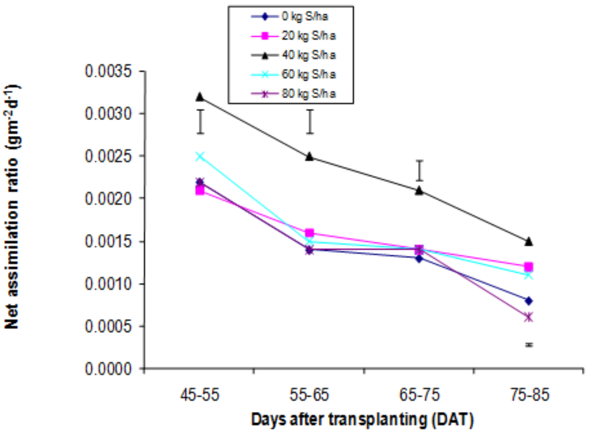

Fig 9. Effect of different doses of sulphur on net assimilation rate at different days after transplanting. The vertical bars indicate LSD at 0.05 level of significance.

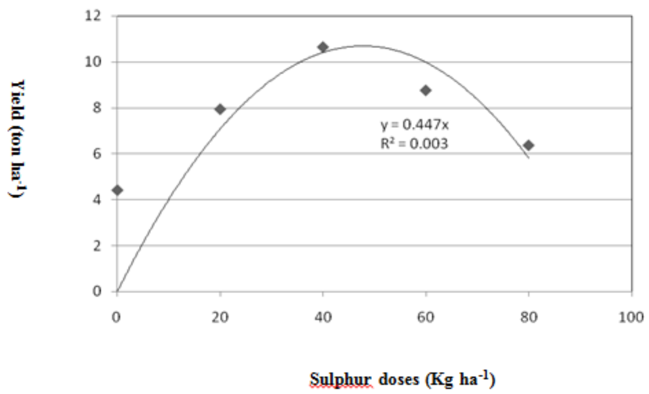

Fig 10. A response curve on effect of different doses of sulphur on yield of onion.

Experimental treatments and design

Five different doses of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}) including control were evaluated to determine the effective dose based morpho-physiological and yield attributes of onion. The popular variety was Faridpuri Bhati. The whole land was well fertilized with 250, 200, 150 kg ha^{-1} of urea, triple super phosphate and murate of potash and 10 tha^{-1} Cowdung, respectively and was applied equally to all treatments. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Unit plot size was 2 m x 1 m. Forty-day-old seedlings were transplanted in the plot with a spacing of 20 cm x 15 cm on 2 January, 2008.

Data collection

A total of five harvests (5 plants/replication/harvest) were made for recording data on some morpho-physiological attributes of onion only. The first crop sampling was done at 45 days after transplanting and continued at an interval of 10 days up to 85 DAT. The plants were separated into roots, bulbs, stems and leaves and the corresponding dry weights were recorded after oven drying at 80 ± 2^0C for 72 hours. The total dry matter was calculated from the summation of dry weights of roots, bulbs, stems and leaves taken in an electronic balance. Other morpho-physiological attributes of onion was also determined by their respective method.
The following growth parameters were computed using the formula given by Hunt (1978).

Leaf area index (LAI): LAI is the ratio of leaf area to its ground area. It was determined by the following formula:

$$LAI = \frac{LA}{A} \times 100,$$ Where;

LA = Leaf area (cm^2)
A = Unit land area (cm^2)

Absolute growth rate (AGR):

$$\text{i.e. } AGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ g plant} - 1 \text{ day} - 1$$

Where;
W_2 and W_1 are the dry mass (DM) at time T_2 and T_1, respectively.

Relative growth rate (RGR):

$$\text{i.e. } RGR = \frac{\text{Log } W_2 - \text{Log } W_1}{T_2 - T_1} \text{ g g} - 1 \text{ day} - 1$$

Where;
W_2 and W_1 are the DM at time T_2 and T_1, respectively.

Net assimilation rate (NAR):
1

$$\text{i.e. } NAR = \frac{W_2 - W_1}{T_2 - T_1} \cdot \frac{\text{Log } LA_2 - \text{Log } LA_1}{LA_2 - LA_1} \text{ g cm} - 2 \text{ day} - 1$$

Where; LA_2 and LA_1 are leaf area at time $T_2$and T_1, respectively.

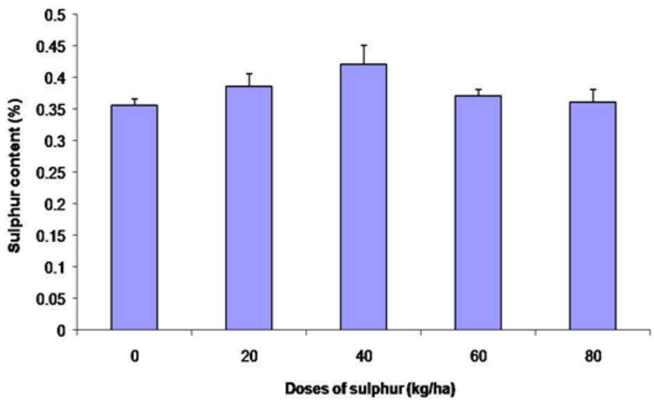

Fig 11. Effect of different doses of sulphur on sulphur content in onion bulb at 45 DAT. The vertical bars indicate standard error.

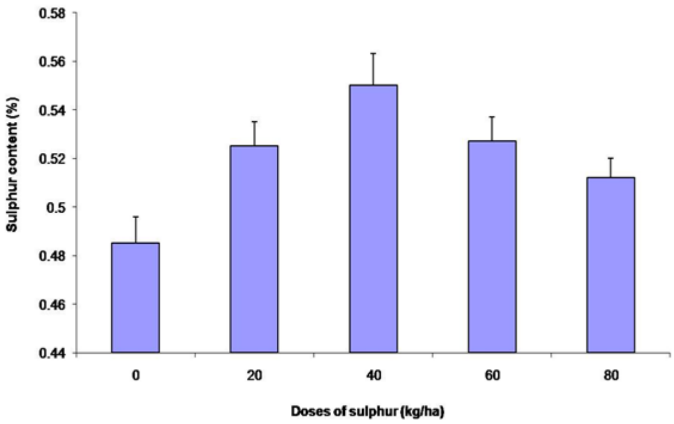

Fig 12. Effect of different doses of sulphur on sulphur content in onion bulb at 85 DAT The vertical bars indicate standard error.

Determination of sulphur content

The concentration of sulphur in the extract was determined turbidimetrically using a spectrophotometer. Turbidity was developed using barium chloride ($BaCl_2$, $2H_2O$) and was measured at wave length of 425 nm following ASI method (Hunter, 1984).

Statistical analysis

The experiment was done in a Randomized Complete Block Design (RCBD) with four replications. The data collected on different parameters under the experiment were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986). The differences between pairs of means were compared by Duncan's multiple range test (DMRT) as stated by Gomez and Gomez (1988).

Conclusions

The experiment was carried out to investigate the effect of different doses of sulphur on growth and yield performance of onion. Different does of sulphur played important roles on growth, yield and yield attributes. Results of the experiment revealed that almost all the characters studied were significantly affected by different doses of sulphur. However, number of splitted bulb, bulb diameter, neck diameter, and neck bulb ratio were not affected by different doses of sulphur application. Number of leaves plant^{-1} increased up to a certain growth stage and then declined. Dry weight of root, dry weight of bulb, dry weight of stem, and TDM showed an increasing trend up to last stage of growth. Application of 40 kg S ha^{-1} showed the highest yield (10.65 t ha^{-1}) among the other doses of sulphur. Application of 250, 200, 150 kg ha^{-1} of urea, triple super phosphate and murate of potash and 10 tha^{-1} cowdung and 40 kg S ha^{-1} might be an optimum combination for onion production in Sonatola series of Old Brahamaputra Flood Plain Soil (AEZ-9), Bangladesh.

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