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Sulphur Effects on Growth Responses and Yield of Onion

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Abstract: Field experiments were conducted on a clay loam belonging to Chhiata series of Gray Terrace soil, Gazipur, Bangladesh for three years, from 1995 to 1998, to study the effect of seven levels of sulphur (0, 15, 30, 45, 60, 75 and 90 kg ha^{-1}) on total dry matter (TDM) accumulation pattern, crop growth rate (CGR), relative growth rate (RGR) at various stages of growth, yield components and bulb yield of onion. The accumulation of total dry matter (TDM) and the pattern of dry matter of onion throughout the experimental period showed considerable variation due to sulphur levels. The rate of TDM production was maximum at 60-75 days after transplanting (DAT) irrespective of sulphur levels. CGR values were increased progressively over time reaching peak at 60-75 DAT and thereafter declined sharply till 105 DAT. RGR from its highest value at early growth stage continued to decrease with crop age. Highest TDM, CGR, RGR, yield parameters and bulb yield were obtained from 45 kg S^{-1} along with a blanket dose of 120 kg N, 90 kg P_2O_5, 90 kg K_2O, 5 kg Z ha^{-1} plus 5 t cowdung ha^{-1}. Least TDM and bulb yield were recorded for control recorded for control treatment. Application of 45 kg S ha^{-1} also produced marketable bulbs of 50 g size while 71% of the bulbs were of < 15 g size in the control plots.

Key words: Growth index, sulphur fertilizer, yield, onion

Introduction

Onion (*Allium cepa* L.) is an important spice crop grown all over Bangladesh during the rabi (winter) season. The average yield of onion in Bangladesh in 4.12 t ha^{-1} (BBS, 1998) which is very low as compared to other onion production countries of the world. The average world yield of onion at present is about 17 t ha^{-1} (FAO, 1999). The yield of onion in Bangladesh is low primarily due to lack of using yielding varieties, very low level of fertilizer, inadequate cultural management and also due to lack of acquaintance of the farmers with the role of sulphur in crop production. Moreover, most of Bangladesh soils are deficient in available sulphur which roughly covers 44% of the total cropped area (Hussain, 1990).

Onion being a cool season crop, temperature and daylength are decisive factors for its growth and bulbing (Siemonsma and Piluck, 1994). The various physiological aspects in relation to dry matter accumulation and distribution in different plant parts are helpful in improving the productivity through fertilization measures as it gives an insight into the factors which lead to differences in productivity. However, onion is an important sulphur-loving crop and sulphur is essentially required for proper growth and yield of crops. Sulphur has been found not only to increase the bulb yield but also improve its quality especially pungency and flavors (Jaggi and Dixit, 1999). Balasubramonian *et al.* (1979) also reported that onion required sulphur fertilization in increasing the dry matter production have been reported by Singh and Rathi (1987). Sulphur containing secondary compounds are not only of importance for nutritive value and flavors but also for resistance against pest and diseases (Bell, 1981). Sulphur deficient plants had poor utilization of nitrogen, phosphorus and potash and a significant reduction of catalase activities at all age. Severe sulphur deficiency during bulb development has detrimental effect on yield and quality of onion (Ajay and Singh, 1994). In Bangladesh, there is limited information about the effect of sulphur on dry matter production and their distribution into different plant parts, growth characteristics and yield of onion, consequently the present study was undertaken.

Materials and Methods

Field experiments were carried out on a clay loam belonging to Chhiata series of Grey Terrance Soil, Joydebpur, Gazipur, Bangladesh during the rabi (winter) season of 1995-96, 1996-97 and 1997-98. Averaged over years, the pH of the experimental soil is 6.0 with low contents of total nitrogen (0.035%), available phosphorus (7 μg mL^{-1}), available sulphur (10 μg mL^{-1}), potassium (0.15 meq 100^{-1} g soil), zinc (1 μg mL^{-1}) and boron

(0.1 μg mL^{-1}), respectively. The total rainfall during the crop season was 104 mm in 1995-96, 131 mm in 1996-97 and 122 mm in 1997-98.

Seven levels of sulphur fertilizer 0, 15, 30, 45, 60, 75 and 90 kg ha^{-1}, were used as treatment variables. The experiment was set up in RCB design with four replications. The unit plot size 3 x 3 m. Fertilizers at the rate of 120 kg N from urea, 90 kg P_2O_5 from triple super phosphate (TSP), 90 kg K_2O from muriate of potash (MP) and 5 kg Zn from zinc oxide were used as blanket dose. Sulphur fertilizer was used in the form of gypsum (calcium sulphate) as per treatment. Besides, cowdung was applied at the rate of 5 t ha^{-1}. Full doses of TSP, MP, gypsum, zinc oxide, cowdung and 1/3 of urea were applied at final land preparation. Healthy and disease free 55 days old seedlings of onion (cv. Faridpuri) were transplanted on 20 Dec in 1995, 22 Dec in 1996 and 23 Dec in 1997 at a spacing of 20 x 10 cm. The remaining 2/3rd urea were applied in two equal installments at 21 and 40 days after transplanting (DAT) followed by irrigation. Three irrigation was given to the crop at 21, 40 and 70 DAT.

Destructive plant were sampled periodically at 15 day intervals starting from 30 days of emergence to maturity to determine dry matter accumulation. At each sampling, five plants from each plot were harvested and separated into leaf, pseudostem and bulb. The segmented plant parts were dried with at 70°C to a constant weight and final dry weight was taken. The crop was harvested each year in the second week of April when the tips turned yellowish. The harvested bulbs were then selected from each plot for diameter and single bulb weight. The size grade distribution into bulbs were done into four categories viz. <15 g, 15-30 g 30-50 g and 50 g and the number of bulbs in each size grade was recorded. The results were finally expressed as percent basis. Data thus collected were subjected to analysis of variance and means were compared Duncan New Multiple Range Test (DMRT). Crop growth rate (CGR) and relative growth (RGR) were calculated by the formulae of Hunt (1978).

Results and Discussion

Dry matter accumulation: Total dry matter (TDM) is the sum of dry matter accumulation into different components like leaf, pseudostem and bulb. TDM and the pattern of dry matter accumulation over time showed considerable variation among sulphur fertilizer treatments (Fig. 1). Regardless of treatment differences, dry matter accumulation was slow in the early growth phase and later it was increased rapidly up to 105 days. The mean total dry matter during 30 DAT was 47 g m^{-2} and increased rapidly to 110 and 509 g m^{-2} during 45 and 105 DAT, respectively. However, highest rate of TDM production at this growth phase might be due to increased photosynthetic rate, which was favorably influenced, by sulphur fertilizer along with other essential elements resulting in higher leaf number and bulb weight. Consistently higher TDM was observed in plants treated with 45 kg S ha^{-1} at all stage Irrespective of years. Further increase in sulphur dose tended to decrease dry matter accumulation but plants grown without added sulphur fertilizer produced the lowest TDM across the growth stages (Fig. 1). Generally, TDM increased with the advancement of plant age.

The pattern of dry matter distribution into different plants of onion with response to sulphur is shown in Fig. 1. Dry matter partitioning of leaf progressively increased up to 75 DAT and thereafter it declined irrespective of sulphur levels. After attaining the maximum leaf dry weight, the lag phases were the result of leaf senescence and redistribution of dry matter from leaves to bulb. The differences in dry matter of leaves were slow at early stage and widened with the advancement of growth. The rate of increase in dry weight of leaves of onion was maximum during 60 to 75 days across the sulphur levels. Consistently higher dry weight of leaves was observed in plants treated with 45 kg S ha^{-1} at all growth stages. Further addition of sulphur tended to decrease leaf dry weight. On the contrary, the plants grown into bulbs across the growth stages. Development of bulb was maximum between 75 and 105 days. Results on an average of sulphur levels revealed that at 30 DAT, leaves accumulated 33% and bulbs 29%, at 60-75 DAT accumulation of dry matter were 33-41% in leaves and 47-50% in bulb and at 90 DAT accumulation of dry matter were 12% in leaves and 82% in bulbs. The sharp rises in bulb development at later phase is photosynthetic because of adequate quantity of foliage growth allowing optimum movement or partitioning of photosynthates to bulbs resulting in bigger sized bulb with higher dry matter. Obviously, it is not only the higher proportion of bulb dry weight that matters in yield but leaf dry weight in also important. Results indicated that 60-75 DAT in the critical period for development of dry matter in the different plant parts and hence there should not be any production stress at that stage. Application of 45 kg S ha^{-1} was favourable for dry matter production in bulb for three years. Plants treated with 0 kg S ha^{-1} had the lowest dry matter partitioning into bulb resulting lower yield in all the growth phases. In general, partitioning of assimilates at reproductive phase was important in onion for bulb yield.

Crop growth rate (CGR): Sulphur fertilization had profound influence of CGR at different growth stages (Fig. 2). CGR was very low initially, which progressively

Table 1: Bulb number, weight of single bulb, horizontal and vertical diameter of bulb of onion as influenced by sulphur fertilization

Sulphur levels ($kg\ ha^{-1}$)	Bulb number/m^2 at harvest			Weight of single bulb (g)			Horizontal diameter of bulb (g)			Vertical diameter of bulb (cm)		
	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
0	49b	48b	48c	14.18e	14.15e	13.83e	4.05d	3.88e	3.89e	3.92d	4.04d	4.04
15	50b	51ab	51ab	29.14d	29.40d	28.76d	4.84c	4.77d	4.74d	4.03c	4.53c	4.58
30	51b	51ab	51ab	37.73b	35.55b	35.59b	5.30a	5.22b	5.24b	4.79b	4.80b	4.84
45	53a	51a	52a	45.72a	45.44a	45.44a	5.39a	5.38a	5.54a	5.01a	4.91a	5.01
60	53a	51a	50b	44.66a	45.47a	45.71a	5.36a	5.38a	5.44a	5.00a	4.98a	5.02
75	52a	50b	50b	36.33b	36.66b	36.67b	5.09b	4.95c	4.43c	4.85b	4.74b	4.90
90	52a	51ab	49c	34.20c	33.58c	33.88c	5.03b	4.94c	4.88c	4.77b	4.70b	4.83
CV (%)	2.2	2.9	3.3	3.3	3.5	4.2	3.8	4.8	2.8	3.5	4.0	4.7

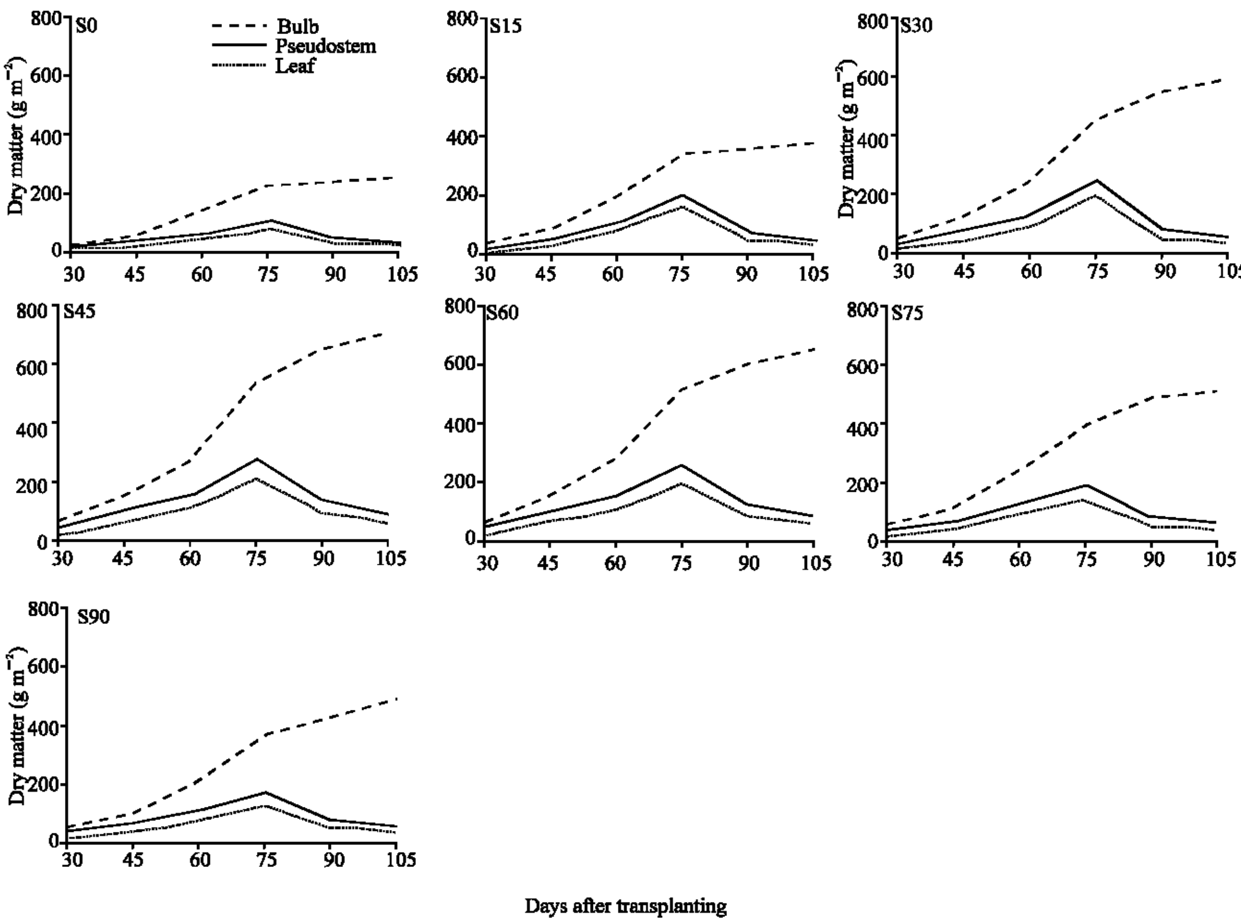

Fig. 1: Dry matter accumulation in different tissues of onion as influenced by sulphur fertilizer growth stages

increased to reach the peak during bulb development period (60-75 DAT) and later decreased irrespective of sulphur levels. This decrease in CGR may partly be due to start of leaf senescence and gradual decrease in photosynthesis. The maximum CGR was recorded with 45 kg S ha^{-1} application and the maximum CGR was found in control treatment across the growth stages. The increase in CGR with sulphur application was possibly due to the consequence of increased leaf size or number. Higher dose of sulphur caused reduction in CGR irrespective of growth stages. There might have been an imbalance in the ratios of other nutrients with that of sulphur and toxicity to plants. The results indicated that a great deal of contribution of sulphur along with other essential elements was apparent towards the increasing and sustaining increased CGR throughout the growing season by increasing plant growth.

Relative growth rate (RGR): The different levels of sulphur applied in this study influenced the RGR at different growth stages (Fig. 3). RGR of onion was highest was highest at 15-30 DAT and decreased

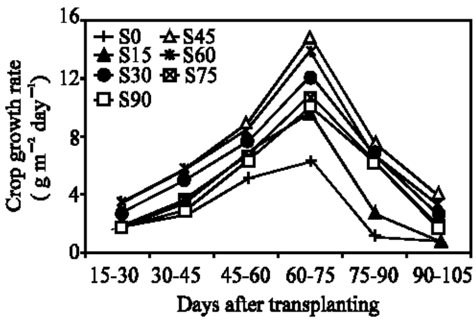

Fig. 2: Crop growth rate of onion at different growth stages as affected by sulphur fertilizer

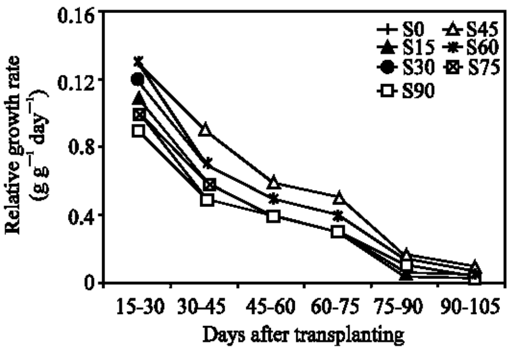

Fig. 3: Relative growth rate of onion at different growth stages as affected by sulphur fertilizer

gradually with the progress in the ontogeny of the crop across the S levels. Later, there was continuous decline in RGR owing probably to concomitant decrease in leaf and assimilation rates. However, the decrease in RGR during the early stages. Plants treated with 45-60 kg S ha^{-1} maintained a higher RGR throughout the growing season. Lower RGR was observed in the control treatment.

Yield and yield attributes: Yield attributes and yields of onion in response to different rates of sulphur fertilizer are presented in Table 1 and Fig. 4. Sulphur fertilizer had significant influence on the weight of single bulb, diameter of bulb (both vertical and horizontal) and bulb yield ha^{-1}. Number of bulbs at harvest varied between 49 to 53 cm 1995-96, 48 to 51 in 1996-97 and 48 to 51 in 1997-98, respectively (Table 1). Number of harvested bulbs did not vary due to variable doses of sulphur fertilizer. Plant mortality due to disease or other biotic factors might have caused the difference. The weight of single bulb ranged 14.18 to 45.72 g in 1995-96, 14.15 to 45.44 g in 1997-98 across the sulphur levels. Weight of single bulb was more in plants treated with 45 kg S ha^{-1}, although plant receiving 45 or 60 kg S ha^{-1} did not differ significantly in bulb weight. Further increase in sulphur fertilizer tended to decrease the single bulb weight irrespective of years.

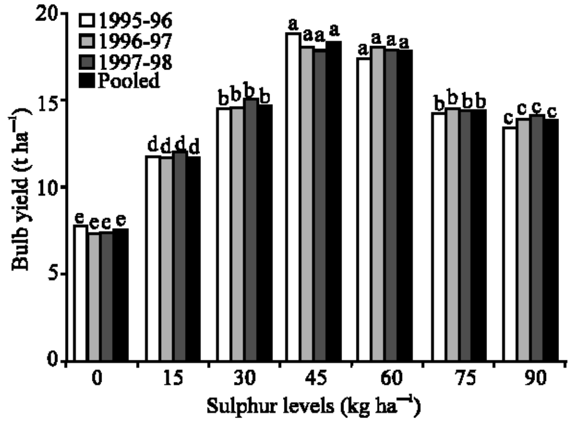

Fig. 4: Bulb yield of onion as influenced by sulphur fertilization

No sulphur application, however, gave the lowest value. The results are in agreement with Ahmed *et al.* (1988). Bulb diameter (both horizontal and vertical) varied significantly due to sulphur fertilization (Table 1). Averaged over the years, horizontal diameter differed from 3.94 to 5.41 cm. It was highest for the plants grown with 45 kg S ha^{-1} and the lowest for those with 0 kg S ha^{-1} across the years. Addition of sulphur rate beyond 45 kg ha^{-1} decreased horizontal diameter drastically. On the contrary, application of 60 kg S ha^{-1} tended to produce more vertical diameter of onion, which was statistically identical with 45 kg S ha^{-1}. Further increase in sulphur rate produced no diameter advantage.

The bulb yield ha^{-1} of onion also varied significantly due to sulphur fertilizer application in all the years (Fig. 4). Bulb yield ranged between 7.67 to 18.92 t ha^{-1} in 1995-96, 7.30 to 18.18 t ha^{-1} in 1996-97 and 7.29 to 18.06 t ha^{-1} in 1997-98 across the S levels. It was highest for the plants grown with 60 kg S ha^{-1} followed by 45 kg S ha^{-1}. The yield advantage of sulphur fertilizer application at 45 kg S ha^{-1} was 148% higher over the control (without sulphur). It could be conclusively inferred that onion yield can be increased with sulphur fertilizer application 45 kg S ha^{-1} and the expected yield is around 18 t ha^{-1}. Jana and Kabir (1990) reported that application of 40 kg S ha^{-1} resulted in higher bulb yield of onion. Singh *et al.* (1996) reported similar results for onion. From Fig. 4, it appears that there was a quantum jump in bulb due to favourable response of sulphur fertilizer along with blanket dose of NPK application, suggesting that the experimental soil was highly deficient in sulphur and also nitrogen phosphorus and potassium that resulted in the yield difference. Moreover, increase in the yield of bulbs up to 45 to 60 kg S ha^{-1} might be due to production of greater number of leaves to increase formation of vegetative structure for nutrient adsorption and photosynthesis and increased production of assimilates to fill the sink, resulting in increased bulb size and weight. Higher dose of sulphur beyond 45 to 60 kg S ha^{-1} depressed yield in all the years might be due to imbalance of nutrients and prevalence of other constraints in soil, which can not be made up by sulphur application (Tandon, 1987). Plants grown without sulphur had the lowest bulb yield of onion. Sulphur deficiency disturbed the balance of nutritional environment in crops (peas) which results in biological inactivation of life process of plants and have adverse effect on plant grown (Singh, 1970). Yield response to applied sulphur followed a quadratic relationship. The regression equation worked out to be: $Y = 7.347+0.354X-0.0032 X^2$, $R^2 = 0.95$. This result indicated that bulb yield of onion was increased with the increase of sulphur application up to certain limit. The value of R^2 indicated that the sulphur levels can attribute to 95% of the total variation in bulb yield. On the other hand, bulb yield was closely associated with TDM per unit area. The regression equation worked out to be: $Y = 5.25+0.0155 X$, $R^2 = 0.97$). The R^2 value (0.97) indicated that 97% of total variation in bulb yield would be accounted for by the linear function of the bulb diameter. The fitted regression model suggests that higher the bulb size, greater will be the yield.

Bulb size distribution: Majority (70.63%) of the bulb were of < 15 g size and 29.4% of them were of 25-30 g size in the control plots (Fig. 5). Addition of sulphur fertilizer brought about a considerable reduction in the proportion of < 15 g sized bulbs. Increasing the levels of sulphur fertilizer upto 45 kg ha^{-1} increased the proportion of bulbs under 30-50 g size and >50 g size and ranged between 21.2 and 67.7%. The reduction of bulb size at higher levels of

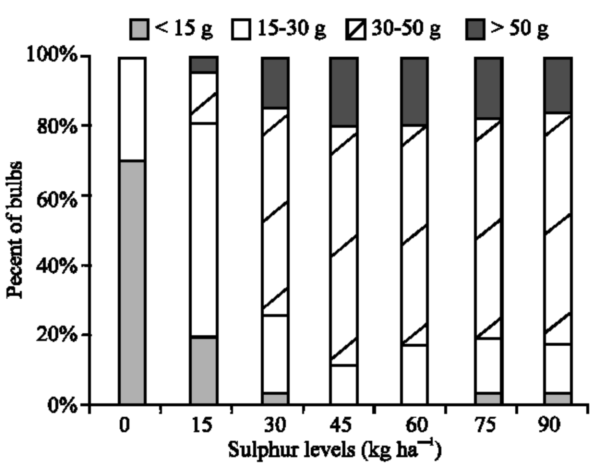

Fig. 5: Percent of bulb (number basis) under different grade as influenced by sulphur fertilization

sulphur (beyond 45 kg ha^{-1}) was possibly due to some barrier to onion nutrition resulting in reductions of bulb size. The results suggested that increased levels of sulphur upto 45 kg ha^{-1} were associated with higher percentage of large size bulbs and thereby increased the yield of onion.

The results of three years study revealed that sulphur is necessary to ensure better grown and productivity of onion. Application of 45 kg S ha^{-1} along with a blanket dose of 120 kg N, 90 kg P_2O_5, 90 kg K_2O and 5 kg Zn plus 5 ton cowdung ha^{-1} in Grey Terrance soil might be optimum for maximizing dry matter production, large size bulb and thereby increase the yield of onion.

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