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IMPACT OF SULFUR LEVELS ON THE GROWTH AND YIELD OF WINTER ONION IN LEVEL BARIND TRACT OF BANGLADESH

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Abstract

A field experiment on onion (cv. BARI Piaz-1) was conducted at the Spices Research Centre, Shibganj, Bogura, from October 2018 to March 2019–19 to assess the influence of sulfur (S) levels on onion growth and yield. Five sulfur levels, viz. 0, 15, 30, 45, and 60 kg ha^{-1} were employed in the RCBD trial and replicated thrice. Various S concentrations substantially influenced plant height, number of leaves per plant, bulb diameter and bulb production. Application of 30 kg S ha^{-1} resulted in maximum plant height (50.57 cm), number of leaves plant^{-1} (7.68) at 75 days after transplanting (DAT), bulb diameter (5.24 cm), bulb yield (12.9 t ha^{-1}) and marginal benefit-cost ratio (MBCR) (12.77). From the regression curve, the optimum level of S for the desired yield was determined to be 45 kg S ha^{-1}. Therefore, it may be recommended that application of sulfur @ 45 kg ha^{-1} along with a blanket dose of 100-50-75-4-1.5 kg ha^{-1} of N-P-K-Zn-B and cowdung 5 tha^{-1} for the production of onion bulbs in the agro-ecological zone (AEZ-25) (Level Barind Tract) of Bangladesh.

Keywords: *Allium cepa***,** Winter onion**,** MBCR, Growth, Sulphur, Yield, AEZ-25.

Introduction

Onion (*Allium cepa* L.), a member of Alliaceae family, is a one of the most important vegetable crops grown worldwide due to their economic, nutritional, and medicinal benefits. It is popularly known as 'Peyaz' in Bangladesh grown as spice crop throughout the country during the *rabi* (winter) season. In Bangladesh, during 2022-23, onion is cultivated in 2.036 lakh hectares of land with an annual production of 25.47 lakh metric tons (Anon., 2024). The mean yield is 12.51 ton/ha which is lower in comparison to the world's production (19.3 t/ha). In India average bulb yield is 12.5 t/ha, whereas bulb yield is 41.12 t/ha in the USA. Low fertilizer levels, a dearth of high-yielding quality storable cultivars, inadequate cultural management, and farmers' ignorance and negligence of the significance of sulfur in crop productivity are the causes of Bangladesh's low onion production.

Onion is a highly sulfur-responsive crop as S is an important component of Allicin (allyl thiosulfinate) which is a sulfenic acid thioester. Sulfur is an essential nutrient

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for increasing the productivity and quality of onion bulbs (Lakkineni and Abrol, 1994). Sulfur shortage has been widespread in Bangladesh and most other agricultural areas of the world during the last few decades. The S deficiency issue in Bangladesh's soils has gotten worse due to several factors, including the use of fertilizers like urea, triple super phosphate, muriate of potash, and diammonium phosphate; cultivation of modern high yielding varieties (HYVs); increased cropping intensities; and sparing application of organic manure. As a result, it is now a limiting factor for increased yields and fertilizer efficiency. According to a study conducted by the Soil Resources Development Institute (SRDI) in 2000, about 11.1 million hectares of the nation's land was lack of fertility.

Sulfur deficiency has increased by 11 lakhs in 10,000 hectares of land nationwide in the last 20 years between 2001 and 2020 (Mamun, 2023). Recently, it has been observed that a little over 76 lakh forty thousand hectares, or 51.8% of the land, lack sufficient sulfur (Huda, 2023). It should be noted that in Bangladesh's northern region, soils deficient in sulfur make up approximately 7 M ha, or 52%, of agricultural lands (SRDI, 1999). Roughly 44% of the total cultivated area in Bangladesh comprises soils that are lacking in available sulfur (Hussain, 1990). However, field S fertility is frequently neglected, and crop symptoms of S deficiency can occasionally be misinterpreted for P or N deficits or aluminium toxicity. Sulphur deficiency issues are becoming more common as a result of the widespread use of concentrated fertilizers with low S contents (Hitsuda, *et al.*, 2005). Sulphur status (% of arable lands) under different fertility classes for loamy to clayey soils of upland crops is presented in Fig. 1.

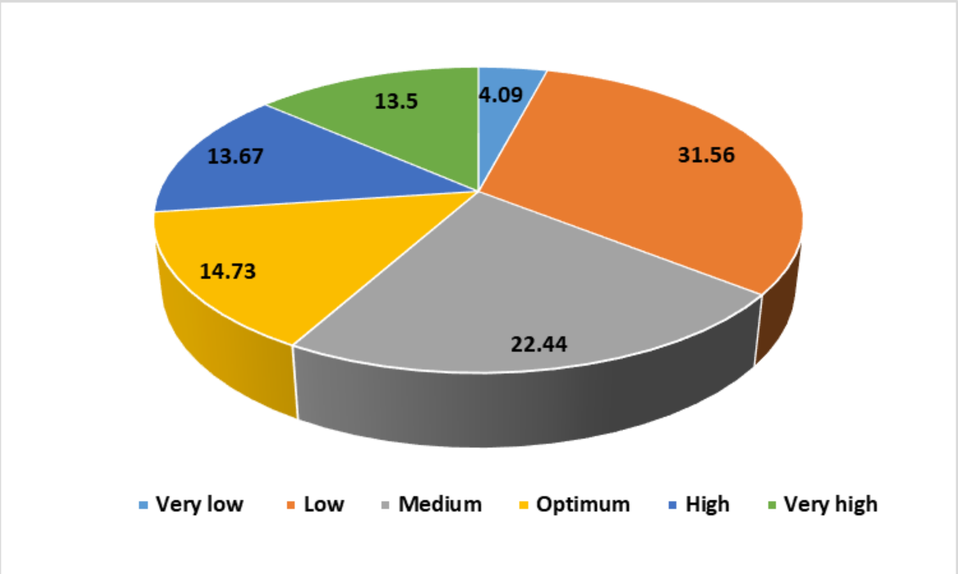

Fig. 1 Sulphur status (% of arable lands) under different fertility classes for loamy to clayey soils of upland crops. (Soil Fertility Atlas Bangladesh, 2020).

Secondary compounds containing S are crucial for disease and pest resistance in addition to their nutritional value and flavor (Bell, 1981). Onion yield and quality are negatively impacted by severe S deficiency during bulb development (Ajay and Singh, 1994). Furthermore, it has been discovered that S improves the quality of bulbs, particularly their pungency and flavors, in addition to increasing their yield (Jaggi and Dixit, 1999). According to Singh and Rathi (1987) as well as Balasubramonian *et al.* (1979), fertilizing onions with S increased their production of dry matter. At all ages, sulfur-deficient plants showed a marked decrease in catalase activity as well as poor utilization of phosphorus, nitrogen, and potash. There is little information available in Bangladesh regarding the influence of sulfur on the production of dry matter, its distribution among various plant parts, growth traits, and yield of onion. The current study, therefore, was conducted to evaluate how different sulfur levels affected onion growth and yield.

Materials and Methods

The study was conducted at the research field at Spices Research Centre (SRC) research field in Shibganj, Bogura, Bangladesh year 2018–19, to ascertain the influence of varying sulfur levels on onion growth and yield. The experimental site was part of the AEZ-25: Level Barind Tract and was located at latitude 24°51′ N and longitude 89°22 E. with 1762 mm of annual rainfall on average, it had a subtropical climate. Composite soil samples (0–15 cm depth) were taken from the experimental field and analyzed to assess the soil's initial nutrient status (Table 1) experimental plots.

Table 1. Analytical value of the experimental soil during 2017-18 and 2018-19

Texture	pH	OM	Ca	Mg	K	Total N	P	S	B	Zn	Cu
		%	(meq/100g soil)			%	(ug/g soil)				
2017-18											
Clay loam	5.8	1.02	2.4	0.93	0.33	0.06	15.2	8.3	0.13	1.25	0.12
2018-19											
Clay loam	5.8	1.00	2.2	0.95	0.37	0.058	15.28	9.3	0.15	1.26	0.11
Critical level	-	-	2.0	0.8	0.20	-	14	14	0.2	0.6	0.2

A randomized complete block design (RCBD) was followed with three replications of five different levels of sulfur, viz. 0, 15, 30, 45, and 60 $kgha^{-1}$. Unit plot dimension was 3 m x 2.5 m. A blanket dose of fertilizer @ 100-50-75-1.5-4 kg ha^{-1} of N-P-K-B-Zn plus cowdung 5 t ha^{-1} was used with treatment doses of S of the experiment. During the final land preparation, urea, triple super phosphate, and muriate of potash along with a treatment dose of gypsum (form of S) were applied as a part of the blanket dose of one-third of nitrogen and the entire amount of potassium, zinc, and boron, respectively. Two weeks prior to the last stage of land preparation, total amount of well-decomposed cowdung was used. In the thirdandfifth weeks following transplanting, the remaining two thirds of the urea was applied in two equal installments as top dressing 25 and 45 days after transplanting (DAP). Forty five days old BARI Piaz-1 seedlings were transplanted on 11 December 2018 maintaining 10 cm in both row and plant spacing.

Weeding and mulching were done as needed. Water cane with fine meshed nozzle was used to irrigate the young plants. Throughout the cropping season, three irrigations were applied. Pesticide Furadan 3G @ 20 kg ha^{-1} was used as a soil treatment to prevent cutworms (*Agrotis ypsilon*). Onion purple blotch disease was managed by applying fungicide Rovral 50 WP and Amister Top to the crop alternately at the right time.

When flower stalks appeared during the crop's growing season, they were clipped off to prevent bolting. The crop was harvested on March 23 2019 since eighty per cent of the plants reached maturity, meaning that most of their leaves had dried out and they collapsed from the neck. On 25, 50, and 75 DAT, growth data was recorded at the vegetative stage. The final harvesting of onion was done at 100 DAT. Ten randomly chosen onion plants were taken during harvesting from each plot and their yield attributes were recorded. Plot wise bulb weight was noted and converted to yield (tons) per hectare. The amount of sulfur in the onion extract was measured with a spectrophotometer using the turbidity method (Hunter, 1984). Barium chloride ($BaCl_2$. $2H_2O$) was used to create turbidity and the ASI method was used to measure it at a wavelength of 425 nm (Hunter, 1984).

R statistical software (http://www.R-project.org) was used to analyze the data. Analysis of variance was used to examine the yield and yield-contributing traits (the Agricolae R package and anova function; De Mendiburu, 2017). The regression analysis was done with the help of R software.

Mean separation was done by Least Significant Different (LSD) test.

Results and discussion

Effect of Sulfur levels on growth of onion

Plant height

Plants treated with varying amounts of sulfur fertilizer were noticeably taller than those treated with absolute control (Fig. 1). Indeed, throughout the growing season, the plant heights under the various treatments were statistically identical. Throughout the growing season, the plant height was at 75 DAT slightly declined at harvest, but T_3 (30 kg ha^{-1}) always gave the tallest plant at each DAT. At 75 DAT, application of 30 kg S ha^{-1} resulted in tallest plants (50.57 cm), which was statistically similar to 45 and 60 kg S ha^{-1}, (Fig. 1). The control (0.0 kg S ha^{-1}) produced the smallest plant (38.5 cm) at 75 DAT. Anwar *et al. (*2001) and Forney *et al. (*2010) both reported similar results indicating that sulfur is necessary for healthy vegetative growth and bulb development in onions.

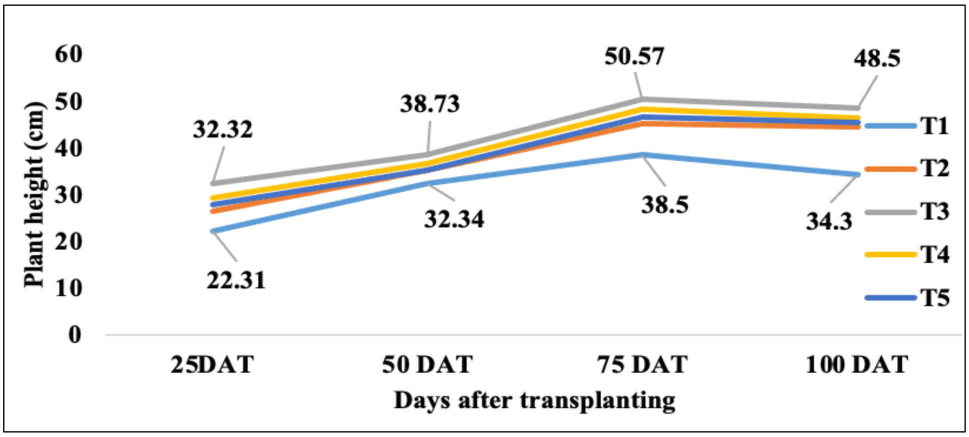

Fig. 1. Effect of different sulphur levels on plant height of onion at different DAT.

Number of leaves per plant

The number of leaves per plant^{-1} showed no discernible change at 25 DAT ranging from 3.14 to 4.32, with T_3 (30 kg S ha^{-1}) exhibiting the highest leaf number and T_1 (control) exhibiting the lowest leaf number (Fig. 2). Regardless of treatments, the number of leaves increased as the plant grew and reached its peak 75 DAT ranging from 5.52 to 7.68. It is reported that sulfur fertilizer produced the highest plant height, number of leaves per plant, bulb diameter, bulb weight, and yield (Dabhi *et al.*, 2004; Jaggi, 2005, and Nasreen *et al.*, 2007).

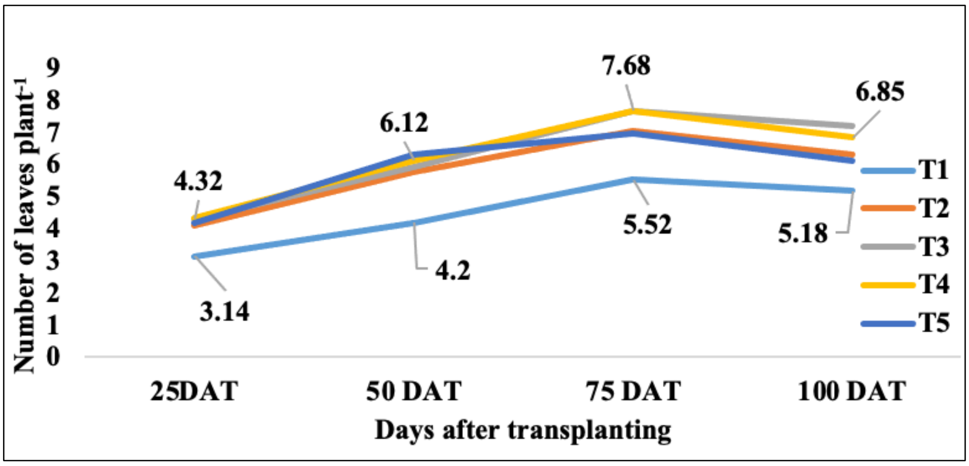

Fig. 2. Effect of sulphur on the number of levels plant^{-1} of onion at different DAT.

Effect of Sulfur levels on yield and yield components of onion

Single bulb weight, bulb size (diameter and length) and yield were significantly influenced by different levels of sulfur (Table 2).

Bulb length

The maximum length of bulb was obtained at 30 kg S ha^{-1} (4.03 cm), which was statistically similar to 45 kg S ha^{-1} (3.84 cm) and 60 kg S ha^{-1} (3.79 ha-1) (Table 2). The control treatment recorded the lowest bulb length (2.94 cm).

Bulb diameter

The fertilization with sulfur caused a significant variation in bulb diameter (Table 2). Bulb diameter varied between 3.57 and 5.24 cm due to the different levels of sulfur application. The plants with the largest bulb diameter were those treated with 30 kg S ha^{-1} (5.24 cm) identical with 45 kg S ha^{-1} (5.22 cm) and 60 kg S ha^{-1} (5.21 cm) and the control treatment gave rhe lowest bulb diameter (3.57 cm).

Weight of single bulb

The weight of a single bulb ranged from 16.98 to 34.08 g with various S levels (Table 2). The maximum single bulb weight (34.08g) was observed at 30 kg S ha^{-1} (34.08 g) closely followed by 45 kg S ha^{-1} (29.18 g) and 60 hg S ha^{-1} (31.3 g). The weight of a single bulb was significantly affected by the plant receiving 30 kg S ha^{-1}, but it tended to decrease as more sulfur fertilizer was added. The lowest bulb weight was obtained from the control (no S (16.98 g). The outcomes concur with those of Ahmed *et al*. (1988). The outcome may be explained by sulfur's beneficial effects on lowering soil pH, boosting flocculation of soil particles, enhancing soil structure, and raising the availability of specific plant nutrients in the soil (El-Galla *et al.*, 1989). Another reason could be that onions require more sulfur than other crops do (Schultz *et al.*,1966), or that sulfur is needed for the synthesis of coenzyme A and amino acids, which are necessary for the elaboration of proteins, as well as for the formation of specific disulfide linkages that have been linked to the structural properties of plant protoplasm (Marschner, 1998).

Table 2. Yield and yield components of onion bulb as influenced by different levels of Sulfur fertilizer

Treatments (kg ha^{-1})	Length of bulb (cm)	Diameter of bulb (cm)	Wt. of single bulb (g)
T_1: S= 0	2.94d	3.57c	16.98e
T_2: S= 15	3.41c	4.78bc	19.58d
T_3: S= 30	4.03a	5.24a	34.08a
T_4: S= 45	3.84ab	5.12a	29.18ab
T_5: S= 60	3.79ab	5.21a	31.3ab
Significance Level	**	**	**
CV (%)	4.98	8.91	5.67

In a column, means followed by the same letters did not differ significantly. '**' indicates significant at 1% level of significance, CV= Coefficient of variation

Bulb yield

With the application of sulfur bulb yield significantly increased up to 30 kg S ha^{-1} and then declined (Table 3). The maximum bulb yield (13.35 tha^{-1}) was obtained from the application of 30 kg S ha^{-1} followed by 45 kg ha-1 (12.90 t ha^{-1}) and 60 kg S ha^{-1} (12.85 t ha^{-1}). Production of taller plants with more leaves may result in increased vegetative structure for nutrient absorption and photosynthesis, as well as increased assimilate production to fill the sink and increase bulb size and weight. However, this could explain any increase in bulb yield of less than 45 or 60 kg S ha^{-1}. Beyond 30 kg S ha^{-1}, however, a negative response to sulfur was noted. Singh and Rathi (1987) also reported similar results. According to Nasreen *et. al.* (2007), fertilizing with nitrogen and sulfur was found to increase the availability of nutrients in the soil, and plant uptake may be the result of synergistic effects. Another explanation might be that onions require more sulfur than other crops, and their needs are higher (Marschner, 1995). According to Tisdale and Nelson (1985) and El-Shafie and El-Gamaily (2002), sulfur plays a significant role in the production of plant protein and certain hormones. It is also essential for enzymatic activity, chlorophyll formation, the synthesis of certain amino acids, and vitamin synthesis. As a result, sulfur has a positive effect on onion yield. Singh and singh (1997) demonstrated that the highest mean yield values were attained by onions that received up to 40 kg of S ha^{-1}. The influence of sulfur on onion yield may be explained by the significant role sulfur plays in the synthesis of certain hormones and plant proteins. Additionally, sulfur is essential for enzymatic activity, the formation of chlorophyll, the synthesis of certain amino acids, and the synthesis of certain vitamins. As a result, sulfur promotes healthy vegetative growth, which increases onion yield.

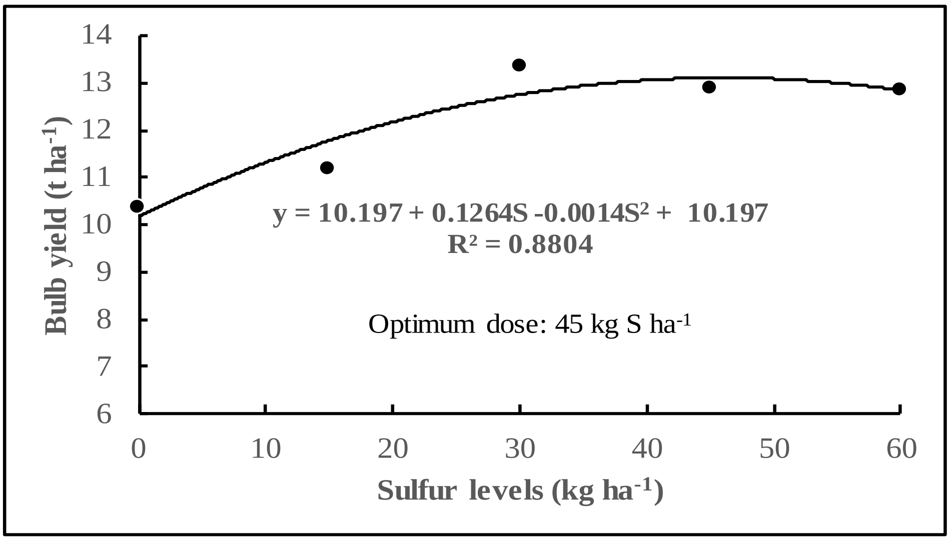

Fig. 3. Relationship between sulfur levels and bulb yield of onion.

Relationship between sulfur levels and bulb yield of onion

According to polynomial regression analysis, there was a positive correlation (R^2= 0.8821) between sulfur and bulb yield (Fig. 3). This result indicated that the bulb yield of onion was increased with the increase of sulfur application up to a certain limit (30 kg ha-1) beyond which yield declined. Based on the regression curve, the optimal level of S for yield was determined to be 45 kg S ha^{-1}. The R^2 value 0.8804 indicated that 88.04% yield was due to S application and the rest 11.94% yield was due to other factors influenced the onion crop.

Nutrient uptake

Considerable differences were noted between the sulfur levels in terms of nutrient concentration and uptake (Fig. 4 and 5). The concentration of sulfur in onion bulbs increased as the amount of sulfur was applied. Application of sulfur @ 30 kg ha^{-1} resulted in an uptake of 57.41 kg ha^{-1} (Fig. 5); this was found to be significantly higher than the values recorded with the remaining levels.

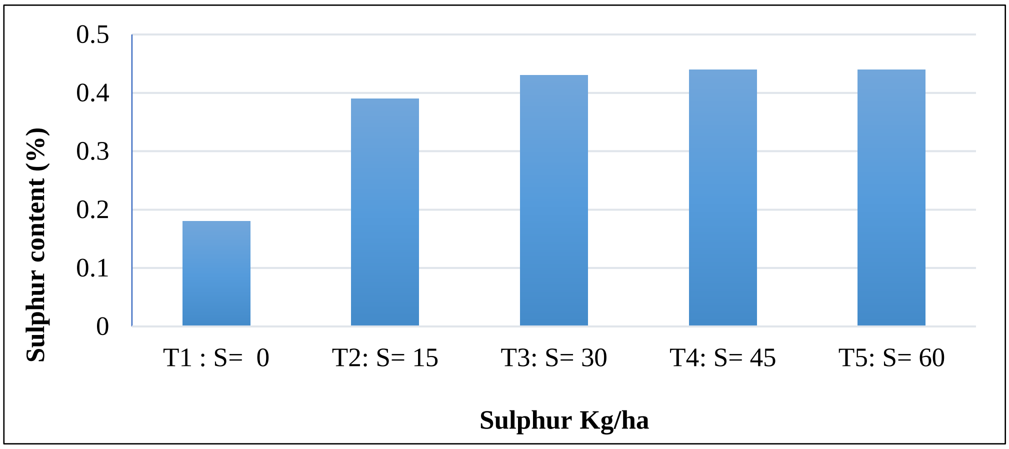

Fig. 4 Effect of various sulfur levels on sulfur concentration in onion (*Allium cepa* L.).

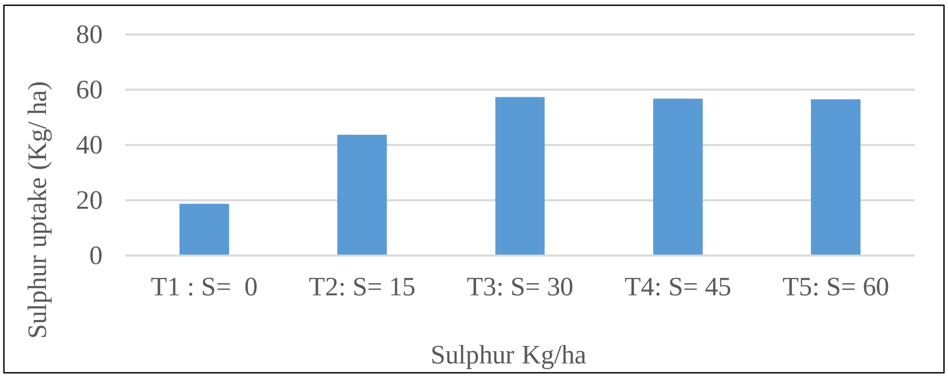

Fig. 5 Effect of sulfur various levels on sulfur uptake in onion (*Allium cepa* L.).

The main function of sulfur in balanced nutrition and in physiological processes such as the synthesis of sulfur-containing amino acids and the development of a profused root system, which leads to increased nutrient uptake and ultimately increases photosynthesis, may be the cause of the increase in growth, yield, and yield-related attributes. Better quality, increased nutrient uptake, and sustained nutrient bulb up in the soil have also reported similar findings. (Dudhat *et al.*, 2011; Jaggi, 2004; Nasrin *et al.*, 2007).

Economic performance

Table 3 presents an economic study of onion cultivation. Treatment T_3 (S= 30 kg ha^{-1}) had the highest marginal benefit-cost ratio (MBCR) (12.77). In respect of of MBCR, it might, therefore, be suggested to use 30 kg S ha-^{1} in addition to a blanket dose of 100-50-75-4-1.5 kg ha-1 of N-P-K-Zn-B plus 5 t ha^{-1} cowdung to increase onion bulb yield.

Table 3. Economic performance of different treatment combinations on bulb yield of onion

Treatment (S kg ha^{-1})	Bulb Yield (t ha^{-1})	Gross income (Tk ha^{-1})	Additional yield over control (t ha^{-1})	Additional income over control (Tk ha^{-1})	Cost of treatment (TK ha^{-1})	Net income (TK ha^{-1})	MBCR
T_1: S= 0	10.39	155850	-	-	0	-	-
T_2: S= 15	11.2	224000	0.81	16200	4150	12050	2.90
T_3: S= 30	13.35	267000	2.96	59200	4300	54900	12.77
T_4: S= 45	12.90	258000	2.51	50200	4450	45750	10.28
T_5: S= 60	12.85	257000	2.46	49200	4600	44600	9.69

MBCR= Marginal benefit-cost ratio, [Price of Onion bulb @Tk. 20.00 per kg; Gypsum: Tk. 10/kg Cost of human labour (fertilizer application): Tk.400/person/day.

Conclusion

The experimental results revealed that variation in sulfur levels had a significant influence on yield, growth, and yield contributing characteristics. Based on the information supplied so far, it might be suggested that the application of 30 kg S ha^{-1} generated the best yield (13.35 t ha^{-1}) when compared to the other sulfur doses. The optimum dose of S determined from the regression curve was 34.77 kg ha-1. Application of fertilizers in the form of urea, TSP, MoP, Zinc sulphate and boric acid @ 100-50-75-4-1.5 kg ha-1 of N-P-K-Zn-B plus 5 t ha-^{1} cowdung with 45 kg S ha^{-1} supplied from gypsum may be the best combination for onion production in Level Barind Tract (AEZ-25) of Bangladesh.

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