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Growth and Yield of Onion as Influenced by Sulphur and Boron with Mulch Materials

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Authors' contributions

This work was carried out in collaboration among all authors. Authors KK and TM planned the experiment and lead the research. Authors SHB, KK and TM designed and carried out the research. Author MMH performed the statistical analysis. Authors SHB and MFS carried out the research on the field. Authors SHB, MUH and MJS collected the data. Authors SHB and MMH wrote the manuscript. Authors MJS, MMA and MFS managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka. During the period from October, 2018 to March, 2019 to find out the growth and yield of onion as influenced by Sulphur and Boron with mulch materials. The experiment consisted of two factors: Factor A: Four doses of Sulphurand Boron fertilizer viz. F_0 = $S_{0kg}B_{0kg/ha}$ (Control), F_1 = $S_{20kg}B_{1kg/ha}$, F_2 = $S_{40kg}B_{2kg/ha}$, F_3 = $S_{60kg}B_{3kg/ha}$ and Factor B: Four types of mulch viz. M_0 = No mulch and no irrigation, M_1 = Black polythene, M_2 = Water hyacinth and M_3 = Rice straw. There were 16 treatment combinations and experiment was setup in a Randomized Complete Block Design (RCBD) with three replications. In case of Sulphur and Boron treatments at 60 days after transplanting (DAT), the highest plant height 53.38 cm, maximum leaf number 10.48, highest bulb

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length 4.83 cm,, maximum neck diameter (1.31 cm), highest dry matter content (15.98%), dry matter content of leaf (24.74%), single bulb weight (39.93 g), yield per plot (0.80 kg) and yield per hectare (9.98 t) were obtained from F_3 treatment. Among the mulch materials, highest plant height at 60 DAT (52.51 cm), maximum leaf number (10.19), highest bulb length (4.52 cm), highest bulb diameter (5.74 cm), maximum neck diameter (1.26 cm), dry matter content of leaf (23.35%), single bulb weight (39.05 g), yield per plot (0.78 kg) and yield per hectare (9.76 t) were obtained from M_1 treatment. In combined effect, the highest plant height at 60 DAT (55.54 cm), maximum leaf number (11.47), longest bulb length (5.51 cm), highest bulb diameter (6.68 cm), maximum diameter of neck (1.42 cm), dry matter content of leaf (27.48%), single bulb weight (42.40 g), yield per plot (0.85 kg) and yield per hectare (11.21 t) were obtained from F_3M_1 treatment ($S_{60kg/ha}$ + $B_{3kg/ha}$ with black polythene mulch). The highest gross return (Tk. 3, 36, 300/ha), net return (Tk. 1, 88, 934/ha) and benefit cost ration (2.28) was obtained from the treatment combination (F_3M_1). Accordingly, for high growth, high yield, and economic point of view, F_3M_1 treatment is recommended in onion cultivation.

Keywords: Benefit Cost Ratio (BCR); boron; mulch materials; onion; sulphur and yield.

1. INTRODUCTION

Onion (*Allium cepa* L.) is by far one of the most important bulb crops and is one of the major popular vegetable crops in the world [1]. But in Bangladesh, it is extensively used as a spice for cooking purposes. Among the spices grown in Bangladesh, onion is ranked the first in respect to production and also in area. An edible portion of 100 g onion bulb contains 1.4 g protein, 11.2 g carbohydrate, 12 mg ascorbic acid, fiber (0.6 g), moisture (86.8 g) and several vitamins like vitamin A (0.012 mg), vitamin C (11 mg), thiamine (0.08 mg), riboflavin (0.01 mg), niacin (0.2 mg) and also some minerals like phosphorus (39 mg), calcium (32 mg), sodium (1.0 mg), iron (0.7 mg) and potassium (157 mg) and 49 calories [2]. It is grown in almost all the districts of Bangladesh, but it is commercially cultivated in the greater districts of Faridpur, Rajshahi, Dhaka, Mymensingh, Comilla, Jessore, Rangpur and Pabna [3]. Onion production in Bangladesh during the year of 2013-2014 was 13, 87,000 metric tons from 3, 73,000 acre of land with an average yield of 3,718 kg/acre which is considered low when compared to other onion producing countries in the world [4]. With the increase in population, the demand as well as the import of onion increases day by day. But due to limitation of land it is not possible to raise the production of the crop horizontally. The expansion of onion cultivation will hamper the cultivation of other profitable crops particularly rice, the staple food grain of Bangladesh. The only way to solve the problem is to increase per hectare yield. The average yield per hectare is about 6.82 tons which is much lower than other developed countries where average production is over 17.5 t ha^{-1} [1].

Successful onion cultivation largely depends on the optimum cultural management practices. This includes judicious application of manures and fertilizers, efficient use of available soil moisture, spacing and time of planting. However, soil fertility is the main factor for increasing production of any crop. Soil nutrient management is therefore, a very vital area of research. In an integrated nutrient management homestead cropping pattern, sole application of either organic manure or chemical fertilizers gave inferior results to their integrated use. Researcher's opinion that some secondary and trace elements like sulpher and boron can play a vital role in increasing the yield of onion seed [5]. Onion is a sulphur loving plant and is required much for proper growth and yield of onion [6]. Sulphur has been found not only to increase the bulb yield of onion but also to improve its quality, especially pungency and flavors [7]. Boron is essential for normal growth and production of sound and healthy vegetables. Boron has been linked with initiation and development of growing points, movement of sugars and starches to developing parts, movement of nutrient elements within the plant, formation of plant hormones affecting growth, root growth and health of fleshy roots, flower and fruit set and quality and flavor of vegetables [8]. Besides this, boron is known to play many important functions in plant metabolism. In the absence of boron, proper development of meristematic tissues of plant does not take place. Boron is necessary for cell division, nitrogen and carbohydrate metabolism, salt absorption and water relation in plant. Boron is also required in the translocation of sugars, starches, nitrogen and phosphorus and synthesis of amino acids and proteins [9].

Out of these, efficient use of soil moisture is very important, because rainfall is scanty during Rabi season in Bangladesh when farmers grow this valued crop. Onions are rather sensitive to drought stress [9]. One single most important factor that influences seed yield is soil moisture therefore, onions require frequent irrigations. The crop requires 350-500mm of water over the growing season [10]; hence adequate moisture possibly through irrigation is important in the production of onions. Onion root system is shallow so it extracts very little water from depths beyond 60 cm. Further, growers have to depend either on natural precipitation or supplemental irrigation for growing onion. On the other hand, irrigation feasibilities are not sufficient in all the regions of the country. Sometimes pump cannot lift water in dry season due to lowering of water layer. As a result, the production of onion is hampered to a great extent. Soil moisture is lost through two main processes: i) Evaporation from soil; and ii) Transpiration through plant leaves. Conservation of soil moisture may help in preventing the loss of water through evaporation permitting maximum utilization of moisture by plants. However, onion growth and development is greatly influenced by mulching and irrigation [10].

Use of various mulches like black polythene, transparent polythene, rice straw, saw dust, water hyacinth reported to conserve soil moisture efficiently in garlic and onion as reported by many workers [11,12]. Again, Islam et al. [13] reported that different types of mulches including rice straw and polythene significantly increased the growth and yield of onion.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the Horticulture Farm of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from October 2018 to February 2019. The experimental site was located on an elevation of 8 meters above the sea level in Agro-ecological zone of "Madhupur Tract" (AEZ-28) [14].The soil was sandy loam and medium high land in texture with the pH value of 5.62.

2.2 Experiment Frame Work

The research consisted of two factors: Factor A: Four doses of Sulphur and Boron fertilizers viz. F_0 = $S_{0kg}B_{0kg/ha}$ (Control), F_1 = $S_{20kg}B_{1kg/ha}$ (Sulphur 20 kg/ha and Boron 1 kg/ha), F_2 = $S_{40kg}B_{2kg/ha}$ (Sulphur 40 kg/ha and Boron 2 kg/ha), F_3 = $S_{60kg}B_{3kg/ha}$ (Sulphur 60 kg/ha and Boron 3 kg/ha) and Factor B: Four types of mulch viz. M_0= No mulch and no irrigation, M_1 = Black polythene, M_2 = Water hyacinth and M_3 Rice straw. The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 390 m^2 was divided into three equal blocks, representing the replications, each containing 16 plots. Thus, the total numbers of unit plots were 48. Each measuring 1 m x 0.8 m (0.8 m^2). The treatment combinations of the experiment were assigned at random into 16 plots of each at 3 replications. The distance retained between two plots was 20 cm and between blocks was 20 cm. Black polythene was spread on the plot just before transplanting where water hyacinth and rice straw were used as mulch materials just a week after transplant.

2.3 Statistical Analysis

The data obtained for different parameters were statistically analyzed by MSTAT-C computer package. The significance of the difference among the treatment combinations means was compared by LSD test at 5% level of probability [15].

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Results showed significant differences on plant height with the application of different levels of sulphur and boron fertilizers combination at 15, 30, 45 and 60 day after transplanting (DAT) of onion plants (Table 1). At 15, 30, 45 and 60 DAT, the highest plant heights(18.56 cm, 28.70 cm, 39.35 cm and 53.38 cm, respectively). At 15, 30, 45 and 60 DAT shortest plant heights (15.62 cm, 23.81 cm, 33.66 cm and 47.88 cm) was obtained from the treatment F_0 (control). Similar results were also reported by Paul et al. [16]. On the other hand, at 15, 30, 45 and 60 DAT, the maximum plant heights (18.23 cm, 27.96 cm, 38.77 cm and 52.51 cm, respectively) were recorded from M_1 whereas minimum plant heights (16.27 cm, 27.75 cm , 34.99 cm and 48.85 cm respectively) were recorded from M_0 (Table 2). Combined effect of sulphur and boron with different mulch materials also showed significant difference on the plant height of onion at 30, 45 and 60 DAT (Table 3). At 15, 30, 45 and 60 DAT, the longest plant heights (19.58 cm,

29.92 cm, 41.00 cm and 55.54 cm) were recorded from the F_3M_1 treatment ($S_{60kg/ha}$ and $B_{3kg/ha}$ with black polythene mulch) while, the shortest plant heights (14.16 cm, 22.67 cm, 31.29 cm and 47.13 cm, respectively) were obtained from F_oM_o

3.2 Number of Leaves per Plant

Significant variation was observed in the average no. of leaves per plant due to the effect of different combination of sulphur and boron fertilizer at different growth stage (Table 1). At 15, 30, 45 and 60 DAT, the largest no. of leaves (2.94, 6.26, 6.26 and 10.47, respectively) was recorded from treatment ($S_{60kg/ha}$ and $B_{3kg/ha}$). At 15, 30, 45 and 60 DAT, Minimum no. of leaves (2.44, 4.06, 4.06 and 7.45, respectively) were obtained from the treatment F_0 (control). Similar results were reported by Paul et al. [16]. At 15, 30, 45 and 60 DAT, the maximum no. of leaves (2.85, 5.98, 7.97 and 10.19, respectively) was recorded from M_1 where minimum no. of leaves (2.51, 4.44, 5.77 and 7.93, respectively) was recorded from M_0 (Table 2). Combined effect of sulphur and boron with different mulch materials also showed significant difference on the no. of leaves of onion (Table 3). At 15, 30, 45 and 60 DAT, the maximum no. of leaves (3.08, 7.12, 9.22 and 11.47) were recorded from the F_3M_1($S_{60kg/ha}$ and $B_{3kg/ha}$ with black polythene mulch) treatment while, the minimum no. of leaves (2.24, 3.84, 4.92 and 6.90, respectively) fromF_oM_o.

3.2.1 Bulb length (cm)

The effect of different combination of S and B treatments on the bulb length per plant of onion was found to be significant at harvest (Table 4). The maximum bulb length (4.83 cm) was found from the F_3 treatment ($S_{60kg/ha}$ + $B_{3kg/ha}$) and which was statistically different from all other treatments. The minimum bulb length (2.62 cm) was recorded from the control treatmentF_o . The effect of different mulching treatments on the bulb length of onion per plant was also found to be significant at harvest (Table 5). The highest bulb length (4.52 cm) was recorded from the treatment of M_1 (black polythene mulch), whereas the lowest bulb length (2.99 cm) was obtained from control (M_0) treatment. Combined effect of sulphur and boron with different mulch materials showed significant difference in bulb length as well (Table 6). The longest bulb length (5.51 cm) was found from the treatment of F_3M_1 ($S_{60kg/ha}$ and $B_{3kg/ha}$ with black polythene mulch). And the shortest bulb length (2.25 cm) was found from the F_oM_o ($S_{0kg/ha}$ and $B_{0kg/ha}$ with no mulch and no irrigation) treatment combination.

3.2.2 Bulb diameter (cm)

The variation in diameter of bulb due to different doses of sulphur and boron combination treatments was found statistically significant (Table 4). The maximum bulb diameter (6.00 cm) was found from the F_3 treatment ($S_{60kg/ha}$ + $B_{3kg/ha}$) and the minimum bulb diameter (3.98 cm) was recorded from the F_o treatment (control). All the treatments were statistically different from each other. This might be attributed to the maximum diameter of bulb due to S and B application which in return increased the accumulation of carbohydrates as reported by the Nasreen et al. [17]. Mulching conserve soil moisture and regulate soil temperature thus induce rapid growth of onion plant and proper development of onion bulb resulting in higher bulb diameter [18]. In this study our results confirmed that mulching had significant effect on diameter of onion bulb (Table 5). The largest bulb diameter (5.74 cm) was recorded in M_1 treatment (black polythene mulch) whereas the lowest bulb diameter (4.33 cm) was obtained from control treatment (M_0). Akter [19] stated similar result by using mulch materials. He observed that application of black polythene mulch produce the largest bulb diameter compared to other mulches. Combined effect of sulphur and boron with different mulch materials also showed significant difference on the diameter of onion bulb (Table 6). As the largest bulb diameter (6.68 cm) was recorded with F_3M_1 treatment ($S_{60kg/ha}$ and $B_{3kg/ha}$ with black polythene mulch) which was statistically similar with F_3M_2 treatment (6.44 cm). On the other hand, the lowest bulb diameter (3.67 cm) was obtained from $F_oM_o$treatment which was statistically similar to F_oM_3 treatment (3.85).

3.2.3 Neck diameter (cm)

Non-significant variation was observed in diameter of neck among the different combinations of sulphur and boron treatments (Table 4). The maximum neck diameter (1.31 cm) was obtained from F_3 treatment ($S_{60kg/ha}$ + $B_{3kg/ha}$), whereas the minimum neck diameter (1.09 cm) was recorded from the control F_o. No significant effect on neck diameter was observed with the mulching treatments (Table 5). The maximum neck diameter (1.26 cm) was obtained from M_1 (black polythene mulch) treatment, whereas the minimum neck diameter (1.13 cm)

was recorded from M_0 treatment. The combined effect of S and B with mulch was also found to be statistically non-significant in this respect (Table 6). Maximum neck diameter of bulb (1.42 cm) was obtained from the F_3 M_1 treatment ($S_{60kg/ha}$ + $B_{3kg/ha}$ with black polythene mulch) and minimum diameter of neck (1.03 cm) was found from the combination of F_oM_o treatment.

3.3 Dry Matter Content of Bulb (%)

Percentage of bulb's dry matter content was significantly influenced by the effect of different combination of sulphur and boron treatments (Table 7). The largest dry matter content (15.98%) was found from F_3 treatment and the lowest (11.26%) was recorded from F_0 treatment. Rate of photosynthesis increased with increasing chlorophyll content level. For this reason higher amount of dry matter accumulated in onion bulb. Mulching had significant effect on dry matter content of bulb (Table 8). The highest dry matter content (15.49%) was found from the M_1 treatment followed by the treatment of M_2 (14.53%). And lowest dry matter content (11.86%) was recorded from M_0 treatment. Akter [19] confirmed our findings as he stated that black polythene mulch gave the highest dry matter content of bulb compared to water hyacinth and straw mulch. Dry matter content % of bulb influenced was greatly by the combined application of sulphur and boron with different mulch materials (Table 9). The highest dry matter content (17.62%) was found from the F_3M_1 treatment combination whereas the lowest (10.52%) was found in the F_oM_o treatment.

3.4 Dry Matter Content of Leaf

The effect of S and B fertilizers was found to be statistically significant on the dry matter content % of leaf (Table 7). The plants grown under F_3 treatment gave maximum dry matter content of leaf (24.74%) followed by F_2 treatment. The minimum dry matter content (15.02%) of leaves was found in control treatment. The content of dry matter in leaf was significantly influenced by the different types of mulch (Table 8). The plants grown under black polythene (M_1) treatment gave maximum dry matter content of leaf (23.35%) followed by water hyacinth M_2 (21.68%) and finally the rice straw M_3 (20.40%). The minimum dry matter content (17.38%) of leaves was found in control treatment (Table 8). Similar result was found in a study carried out by Azam [20]. Dry matter content of leaf (%) was greatly influenced by the application of S and B combination with different mulch materials (Table 9). The highest dry matter content of leaf (27.48%) was found from the F_3M_1 treatment, followed by F_3M_2, whereas the lowest dry matter content of leaf (13.42%) was found from F_oM_o treatment.

3.4.1 Individual bulb weight (g)

From the present research work, it was observed that there was significant variation among the treatments in respect to fresh weight of onion bulb due to different of sulphur and boron treatment application (Table 7). The maximum bulb weight (39.93 g) was obtained from F_3 whereas lowest bulb weight (31.05 g) was obtained from F_0. From the above result, it was noted that combined use of S and B increased nutrient availability to plants and much bulb formation occurred. The available soil nutrients supported proper vegetative growth by producing succulent bulb with more protoplasm in the cells in comparison to less available nutrients in onion. Paul et al. [16] also found that combined effect of 1 kg B and 30 kg S/ha produced large onion bulb (24.53 g) compared to other treatments. The application of different mulch materials also significantly influenced the individual bulb weight of onion (Table 8). The highest weight of individual bulb (39.05 g) was found from the M_1 treatment followed by the water hyacinth M_2 (36.78 g) treatment. On the other hand, the lowest bulb weight (32.93 g) was obtained from M_0 treatment. In case of black polythene mulch, plants get sufficient moisture and higher temperature. The mulching favors the reduction of evaporation leading to higher soil moisture content, a reduction in weed growth and the decomposition of added mulches might have also contributed to increase the supply of nutrients and moisture for overall increase in crop yields [21]. Similar result was also found in a study carried out by Akter, 2017 [19]. Weight of single bulb was greatly influenced by the combination of S and B with different mulch materials treatment (Table 9). The highest single bulb weight (42.40 g) was found from the treatment F_3M_1 whereas the lowest single bulb weight (28.40 g) was found in the F_oM_o treatment.

Table 1. Effect of sulphur and boron fertilizers on plant height and number of leaves of onion at different days after transplanting (DAT)

Treatmets	Plant height (cm) at different days after transplanting (DAT)				Number of leaves at different days after transplanting (DAT)			
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**
F_0	15.62	23.81 c	33..66c	47.88 c	2.44	4.06 d	4.06 d	7.45 d
F_1	17.40	26.70 b	36.76 b	50.98 b	2.70	5.17 c	6.93 c	9.05 c
F_2	17.79	27.78 a	38.14 a	51.72 a	2.79	5.73 b	5.73 b	9.83 b
F_3	18.56	28.70 a	39.35 a	53.37 a	2.94	6.26 a	6.26 a	10.47 a
CV %	9.16	11.97	11.68	12.58	8.41	9.67	9.67	10.98
LSD(0.05)	---	2.21	2.62	2.83	---	0.27	0.27	0.58

Table 2. Effect of mulch materials on plant height and number of leaves of onion at different days after transplanting (DAT)

Treatmens	Plant height (cm) at different days after transplanting (DAT)				Number of leaves at different days after transplanting (DAT)			
	15 DAT	30 DAT	45 DAT	60 DAT	15 DAT	30 DAT	45 DAT	60 DAT
Mo	16.27	24.75 c	34.99 c	48.85 d	2.51	4.44 d	5.77 d	7.93 d
M1	18.23	27.96 a	38.77 a	52.51 a	2.85	5.98 a	7.97 a	10.19 a
M2	17.67	27.47 a	37.69 a	51.74 b	2.77	5.57 b	7.49 b	9.65 b
M3	17.20	26.81 b	36.46 b	50.85 c	2.72	5.23 c	6.99 c	9.04 c
CV %	9.16	11.97	11.68	12.58	8.41	9.67	9.25	10.98
LSD (0.05)	---	1.02	1.18	0.74	---	0.21	0.34	0.32

Table 3. Combined effect of sulphur and boron fertilizers with mulch materials on plant height of onion at different days after transplanting (DAT)

Treatments	Plant height (cm) at different days after transplanting (DAT)				Number of leaves at different days after transplanting (DAT)			
	15 DAT	30 DAT	45 DAT	60 DAT	15 DAT	30 DAT	45 DAT	60 DAT
F_oM_o	14.16	22.67 k	31.29 m	47.13 j	2.24	3.84 o	4.92 p	6.90 n
F_oM_1	16.80	24.83 i	36.00 ij	48.79 gh	2.58	4.49 l	5.95 l	8.09 j
F_oM_2	15.99	23.92 j	35.04 k	47.92 i	2.46	4.02 n	5.36 n	7.61 l
F_oM_3	15.55	23.83 jk	32.29 l	47.67 ij	2.46	3.91 no	5.15 o	7.19 m
F_1M_o	16.74	24.75 ij	35.75 jk	48.67 h	2.54	4.31 m	5.61 m	7.88 k
F_1M_1	17.85	28.00 d	37.79 ef	52.71 cd	2.79	5.79 f	7.84 f	10.17 d
F_1M_2	17.61	27.42 e	36.88 g	51.75 de	2.75	5.38 h	7.31 h	9.21 f
F_1M_3	17.41	26.63 f	36.62 h	50.79 e	2.71	5.18 i	6.97 i	8.94 g
F_2M_o	16.87	25.54 h	36.38 i	49.04 fg	2.58	4.72 k	6.20 k	8.38 i
F_2M_1	18.69	29.08 b	40.29 bc	53.00 bc	2.96	6.51 c	8.86 c	11.03 b
F_2M_2	17.93	28.67 c	38.21 d	52.71 cd	2.83	6.08 e	8.18 e	10.47 c
F_2M_3	17.65	27.83 de	37.67 fg	52.13 d	2.79	5.61 g	7.43 g	9.47 e
F_3M_o	17.33	26.04 g	36.54 hi	50.55 ef	2.67	4.91 j	6.34 j	8.57 h
F_3M_1	19.58	29.92 a	41.00 a	55.54 a	3.08	7.12 a	9.22 a	11.47 a
F_3M_2	19.16	29.88 ab	40.63 b	54.58 b	3.04	6.78 b	9.10 b	11.33 a
F_3M_3	18.18	28.96 bc	39.25 c	52.83bcd	2.96	6.23 d	8.43 d	10.54 c
CV %	9.16	11.97	11.68	12.58	8.41	9.67	9.25	10.98
LSD (0.05)	---	0.48	0.32	0.42	---	0.14	0.11	0.17

Columns having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

[F_0 - Control, F_1 - ($S_{20kg/ha}$ and $B_{1kg/ha}$), F_2 - ($S_{40kg/ha}$ and $B_{2kg/ha}$), F_3 - ($S_{60kg/ha}$ and $B_{3kg/ha}$), M_0 - No mulch and no irrigation, M_1 - Black polythene, M_2 - Water hyacinth, M_3 - Rice straw]

3.4.2 Yield per hectare (t)

Yield per hectare varied significantly due to the effect of different doses of sulphur and boron treatment (Table 10). The highest yield (9.98 t/ha) was obtained from the treatment F_3 whereas the lowest yield (7.76 t/ha) was obtained from the treatment F_0 (Table 10). They said that proper or balance doses of fertilization helped better growth and yield of onion. Yield per hectare was significantly influenced by the effect of mulching treatments (Table 11). The highest yield (9.76 t/ha) was found in M_1 treatment (black polythene) followed by M_2 and M_3 in which the yield recorded (9.20 t/ha). The lowest yield (8.23 t/ha) was found in M_0 treatment. These results confirmed our previous findings. Polythene mulch increased soil temperature and moisture. These synthetic mulches reduce weed problems and certain insect pests and also stimulated higher crop yields by more efficient utilization of soil nutrients [22]. Yield per hectare was significantly influenced by the combined effect of S and B fertilizers with different mulch materials (Table 12). The highest yield (11.21 t/ha) was found from F_3M_1 treatment and followed by F_3M_2 whereas the lowest yield (6.56 t/ha) was found from the F_oM_o treatment.

3.5 Economic Analysis

Input costs for land preparation, manure, mulching, irrigation and manpower required for all the operations from seed sowing to harvesting of onion were recorded as per experimental plot and converted into cost per hectare. Price of onion was considered as per market rate. The economic analysis presented under the following headings.

3.6 Gross Income

The combination of different manure and mulching showed different value in terms of gross return under the trial (Table 13). The highest gross return (Tk. 3, 36, 300) was obtained from the treatment combination F_3M_1. The lowest gross return (Tk. 1, 31, 200) was obtained from F_oM_o treatment.

3.7 Net Return

In case of net return, different treatment combination showed different concentration of net return. The highest net return (Tk. 1, 88, 934) was found from F_3M_1 treatment and the second highest net return (Tk. 1, 38, 228) was obtained from F_1M_1 treatment. The lowest (Tk. 25,966) net return was obtained F_oM_o treatment (Table 13).

3.8 Benefit Cost Ratio

The highest benefit cost ratio (2.28) was noted from the treatment combination of F_3M_1 and the lowest benefit cost ratio (1.25) was obtained from F_oM_o treatment (Table 13). From economic point of view, it is apparent from the above results that F_3M_1 treatment was more profitable treatment combination than the rest of the combinations.

Table 4. Effect of sulphur and boron fertilizer on the bulb length, bulb diameter and neck diameter of onion

Treatments	Bulb length (cm)	Bulb diameter (cm)	Neck diameter (cm)
F_o	2.62 d	3.98 d	1.09
F_1	3.78 c	5.01 c	1.16
F_2	4.32 b	5.52 b	1.24
F_3	4.83 a	6.00 a	1.31
CV %	11.45	10.62	8.66
LSD (0.05)	0.137	0.119	---

Table 5. Effect of mulch materials on the bulb length, bulb diameter and neck diameter of onion

Treatments	Bulb length (cm)	Bulb diameter (cm)	Neck diameter (cm)
M_o	2.99 d	4.33 d	1.13
M_1	4.52 a	5.74 a	1.26
M_2	4.16 b	5.36 b	1.22
M_3	3.88 c	5.09 c	1.18
CV %	11.45	10.62	8.66
LSD (0.05)	0.1622	0.134	---

Table 6. Combined effect of S and B fertilizer with different mulch materials on the bulb length, bulb diameter and neck diameter of onion

Treatments	Bulb length (cm)	Bulb diameter (cm)	Neck diameter (cm)
F_oM_o	2.25 o	3.67 n	1.03
F_oM_1	3.04 k	4.40 jk	1.12
F_oM_2	2.68 m	4.01 lm	1.10
F_oM_3	2.49 n	3.85 mn	1.10
F_1M_o	2.81 l	4.21 kl	1.11
F_1M_1	4.50 e	5.62 de	1.20
F_1M_2	4.02 g	5.18 fg	1.19
F_1M_3	3.80 h	5.03 gh	1.15
F_2M_o	3.31 j	4.62 ij	1.17
F_2M_1	5.03 c	6.26 bc	1.31
F_2M_2	4.73 d	5.81 d	1.23
F_2M_3	4.23 f	5.39 ef	1.22
F_3M_o	3.61 i	4.83 hi	1.19
F_3M_1	5.51 a	6.68 a	1.42
F_3M_2	5.21 b	6.44 ab	1.37
F_3M_3	4.99 c	6.07 c	1.25
CV %	11.45	10.62	8.66
LSD (0.05)	0.124	0.239	---

Columns having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
[F_0 - Control, F_1 - ($S_{20kg/ha}$ and $B_{1kg/ha}$), F_2 - ($S_{40kg/ha}$ and $B_{2kg/ha}$), F_3 - ($S_{60kg/ha}$ and $B_{3kg/ha}$), M_0 - No mulch and no irrigation, M_1 - Black polythene, M_2 - Water hyacinth, M_3 - Rice straw]

Table 7. Effect of sulphur and boron fertilizer on dry matter content % of bulb, dry matter content % of leaf and weight (g) of individual bulb

Treatments	Dry matter content of bulb (%)	Dry matter content of leaf (%)	Individual bulb weight (g)
F_o	11.26 d	15.02 d	31.05 d
F_1	13.51 c	20.39 c	35.50 c
F_2	14.88 b	22.66 b	37.95 b
F_3	15.98 a	24.74 a	39.93 a
CV %	9.54	7.56	13.37
LSD (0.05)	0.65	0.85	1.16

Table 8. Effect of mulch materials on the dry matter content % of bulb, dry matter content % of leaf and weight (g) of individual bulb

Treatments	Dry matter content of bulb (%)	Dry matter content of leaf (%)	Individual bulb weight (g)
M_o	11.86 d	17.38 d	32.93 d
M_1	15.49 a	23.35 a	39.05 a
M_2	14.53 b	21.68 b	36.78 b
M_3	13.75 c	20.40 c	35.67 c
CV %	9.54	7.56	13.37
LSD (0.05)	0.49	0.76	0.91

Table 9. Combined effect of S and B fertilizer with different mulch materials on dry matter content % of bulb, Dry matter content %of leaf and weight (g) of individual bulb

Treatments	Dry matter contentof bulb (%)	Dry matter content of leaf (%)	Individual bulb weight (g)
F_oM_o	10.52 l	13.42 k	28.40 j
F_oM_1	12.11 i	17.28 i	34.80 g
F_oM_2	11.41 j	15.02 j	30.73 i
F_oM_3	10.98 k	14.36 j	30.27 i
F_1M_o	11.55 j	17.01 i	32.53 h
F_1M_1	15.34 e	23.13 e	37.47 de
F_1M_2	13.73 g	21.34 f	36.53 ef
F_1M_3	13.43 g	20.10 g	35.47 f
F_2M_o	12.55 h	19.00 h	35.33 fg
F_2M_1	16.89 b	25.52 bc	41.53 bc
F_2M_2	15.84 d	24.25 d	37.87 d
F_2M_3	14.23 f	21.88 f	37.07 de
F_3M_o	12.80 h	20.10 g	35.47 f
F_3M_1	17.62 a	27.48 a	42.40 a
F_3M_2	17.13 b	26.13 b	41.88 b
F_3M_3	16.36 c	25.26 c	39.87 c
CV %	9.54	7.56	13.37
LSD (0.05)	0.30	0.70	0.46

Columns having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[F_0 - Control, F_1 - ($S_{20kg/ha}$ and $B_{1kg/ha}$), F_2 - ($S_{40kg/ha}$ and $B_{2kg/ha}$), F_3 - ($S_{60kg/ha}$ and $B_{3kg/ha}$), M_0 - No mulch and no irrigation, M_1 - Black polythene, M_2 - Water hyacinth, M_3 - Rice straw]

Table 10. Effect of Sulphur and boron fertilizers on the yield of onion per plot and per hectare

Treatments	Yield per plot (kg)	Yield per ha (t)
F_o	0.62 d	7.76 d
F_1	0.71 c	8.88 c
F_2	0.76 b	9.49 b
F_3	0.80 a	9.98 a
CV %	11.42	12.43
LSD (0.05)	31.40	0.32

Table 11. Effect of mulches on yield per plot and per hectare

Treatments	Yield per plot (kg)	Yield per ha (t)
M_o	0.66 d	8.23 d
M_1	0.78 a	9.76 a
M_2	074 b	9.20 b
M_3	0.71 c	8.92 c
CV %	11.42	12.43
LSD (0.05)	18.14	0.21

Table 12. Combined effect of S and B fertilizers with different mulch materials on yield per plot and per hectare

Treatments	Yield per plot (kg)	Yield per ha (t)
F_oM_o	0.57 j	6.56 h
F_oM_1	0.70 g	8.70 fg
F_oM_2	0.61 i	7.68 gh
F_oM_3	0.61 i	7.37 gh
F_1M_o	0.65 h	8.13 g
F_1M_1	0.75 de	9.37 cde
F_1M_2	0.73 ef	9.13 de
F_1M_3	0.71 f	8.87 e
F_2M_o	0.71 fg	8.83 ef
F_2M_1	0.83 b	10.38 bc
F_2M_2	0.76 d	9.47 cd
F_2M_3	0.74 e	9.27 de
F_3M_o	0.71 f	8.87 e

Treatments	Yield per plot (kg)	Yield per ha (t)
F_3M_1	0.85 a	11.21 a
F_3M_2	0.84 ab	10.50 b
F_3M_3	0.80 c	9.97 c
CV %	11.42	12.43
LSD (0.05)	7.83	0.42

Columns having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.
[F_0 - Control, F_1 - ($S_{20kg/ha}$ and $B_{1kg/ha}$), F_2 - ($S_{40kg/ha}$ and $B_{2kg/ha}$), F_3 - ($S_{60kg/ha}$ and $B_{3kg/ha}$), M_0 - No mulch and no irrigation, M_1 - Black polythene, M_2 - Water hyacinth, M_3 - Rice straw]

Table 13. Cost and return of onion cultivation as influenced by fertilizers and mulching

Treatments	Total cost of production (Tk)	Yield (ton/ha)	Gross return (Tk/ha)	Net return (Tk/ha)	Benefit cost ratio
F_oM_o	105,235	6.56	1,31,200	25,966	1.25
F_oM_1	130,513	8.70	2,61,000	130,487	2.00
F_oM_2	114,784	7.68	1,92,000	77,216	1.67
F_oM_3	119,278	7.37	1,84,250	64,972	1.54
F_1M_o	117,593	8.13	1,62,600	45,007	1.38
F_1M_1	142,872	9.37	2,81,100	138,228	1.97
F_1M_2	127,143	9.13	2,28,250	101,107	1.80
F_1M_3	131,637	8.87	2,21,750	90,113	1.68
F_2M_o	119,840	8.83	1,76,600	56,760	1.47
F_2M_1	145,119	10.38	3,11,400	166,281	2.15
F_2M_2	129,390	9.47	2,36,750	107,360	1.83
F_2M_3	133,884	9.27	2,31,750	97,866	1.73
F_3M_o	122,087	8.87	1,77,400	55,313	1.45
F_3M_1	147,366	11.21	3,36,300	188,934	2.28
F_3M_2	131,637	10.50	2,62,500	130,863	1.99
F_3M_3	136,131	9.97	2,49,250	113,119	1.83

[F_0 - Control, F_1 - ($S_{20kg/ha}$ and $B_{1kg/ha}$), F_2 - ($S_{40kg/ha}$ and $B_{2kg/ha}$), F_3 - ($S_{60kg/ha}$ and $B_{3kg/ha}$), M_0 - No mulch and no irrigation, M_1 - Black polythene, M_2 - Water hyacinth, M_3 - Rice straw]

4. CONCLUSION

Considering our findings it could be concluded that combined application of 60 kg sulphur and 3 kg of boron per hectare was found to be the best for higher onion yield. Successful onion production is possible by using mulches, especially black polythene mulch. The highest gross return (Tk. 3, 36, 300/ha), net return (Tk. 1, 88, 934/ha) and benefit cost ration (2.28) was obtained from the treatment combination F_3M_1 ($S_{60kg/ha}$ + $B_{3kg/ha}$ with black polythene mulch). Therefore, F_3M_1 treatment combination is the best for achieving the highest growth, yield, and economic benefit of onion.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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