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Effect of Soil Quantity on Tomato Production at Rooftop Garden

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ABSTRACT

In contemporary times, tomato production in Bangladesh has been on the rise; however, there has not been a corresponding expansion in the land area allocated for tomato farming. In response to the diminishing availability of traditional farmland, this study investigates the effect of soil quantity on tomato production. An experiment was conducted at the rooftop of EXIM Bank Agricultural University Bangladesh, Chapainawabganj. The experiment was set up in a Completely Randomized Design, with six replications and nine pots in each. Three treatments of this experiment were T-1 i.e., small soil quantity (6830 g), T-2 i.e., medium soil quantity (10584 g), T-3 i.e., large soil quantity (15720 g) and each treatment contains three plants growing on three pots each. The plant material was tomato c.v. Mintoo super. Different soil treatments had significant effects on tomato growth and yield-contributing character. The treatment T3 showed significantly highest plant height (71.82 cm), plant girth (3.05 cm), number of fruits plant^{-1} (21.82), leaf length plant^{-1} (14.36 cm), leaf width plant^{-1} (10.95 cm), yield plant^{-1} (1176.4 g), dry weight plant^{-1} (15.17 g), harvest index 42% and yield 1176.4 g. T-1 showed significantly lowest results in all the above-mentioned characters and vice versa. The anatomical aspects of the tomato stem displayed variations, T-1 exhibited larger cortex cells, while T-3 demonstrated also significantly greater diameters in both xylem and pith cells. The BCR was measured 1.77 in the present study. These findings show that growth and yield limitations were caused by the effect of soil quantity. The present study will help to progress knowledge of tomato growers in soil quantity into pots or bags for best production.

Keywords: Mintoo super, Tomato, Soil quantity, Rooftop garden, Yield

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1. INTRODUCTION

The tomato, scientifically known as *Solanum lycopersicum* L., holds an esteemed place in horticulture owing to its versatility, nutritional value, and culinary significance. Tomatoes are grown throughout Bangladesh because of its resilience to a wide range of soil and climate conditions. Although tomatoes are one of the most significant crops that are widely farmed, different agroecological zones have shown differences in output. It contains antioxidants including lycopen, which fights cancer, and is a strong source of vitamins A and C (Bhutani & Kallo, 1983).

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Vegetable crop kinds have been grown on over 1125,000 acres of land, yielding an annual production of 60,000,000 tons for the cropping year 2021–2022 (BBS, 2022). Bangladesh consumes 89 g of non-leafy vegetables on average per day, while the FAO and WHO advise a daily intake of 250 g of vegetables per capita (FAO, 2003). Therefore, Bangladesh has to expand its production and consumption of vegetables. Bangladesh has 6.50% of its land planted to tomato cultivation, with an average yield of 6046.34 kg/acre and a total production of 442299.60 tons (BBS, 2022). Due to rising domestic demand and consumption, the area under tomato cultivation is currently increasing every year. In comparison to many field crops, it is seen as a profitable, less risky, and labor-intensive cash crop with relatively short production cycles (Islam, 2005). Due to urbanization and population growth, it is impossible to halt the loss of arable land in Bangladesh (Fahim et al., 2023). In this case, rooftop gardening can be a huge scope for tomato production as alternatives. However, the success of rooftop tomato cultivation is intricately linked to various factors, with soil quantity playing a pivotal role. Soil quantity, a nuanced aspect of soil management, plays a pivotal role in determining the health and productivity of crops. In the context of tomato cultivation, understanding the impact of soil quantity on key factors such as nutrient availability, water retention, and root development is imperative for optimizing yields. Exploring the effect of soil quantity on tomatoes involves a careful examination of how varying amounts of soil influence crucial physiological processes within the plant. Regarding container size, there is considerable evidence that the physical constraint of the available capacity for root growth inhibits the plant growth (Ruff et al., 1987). From influencing nutrient uptake to regulating moisture levels, the intricate dance between soil and tomato plants unfolds as an intricate symphony, each note resonating with the potential for enhanced productivity or potential challenges. Consequently, a thorough investigation into the nuanced interplay between soil quantity and tomato production is indispensable for devising strategies that maximize yield and quality in rooftop gardens. This exploration delves into the nuanced dynamics of soil quantity and its effects on rooftop tomato production. By examining the interplay between soil quantity and plant development, the present study aims to unravel key insights that can empower urban gardeners and agricultural enthusiasts to enhance the productivity of their rooftop tomato gardens. From substrate choices to container sizes, each aspect contributes to the overall success of rooftop agriculture, and a comprehensive understanding of soil quantity proves instrumental in overcoming the challenges inherent to this unique farming method.

2. MATERIALS AND METHODS

The experiment was conducted on the rooftop of EXIM Bank Agricultural University Bangladesh, between 24°59/N latitude and 88°27/E longitudes, at an altitude of 20.4 m. As plant materials, seedlings of Tomato c.v. Mintoo Super were cultivated. This research maintained the following three treatments, such as T-1 small soil quantity (6830 g), T-2 medium soil quantity (10584 g), and T-3 large soil quantity (15720 g). Thirty days old seedlings were replanted appropriately in bag filled with those quantities of soil.

The experiment was set up in a Completely Randomized Design (CRD) with six replications and 54 plants. In each replication, there were three treatments (T-1, T-2 and T-3), having three bags for each treatment and one tomato plant planted in a bag. When necessary, intercultural operations were carried out to promote better growth and development. Among the intercultural practices used in the experiment were irrigation, insect control, staking and weeding. Harvesting began during the early ripening phase, when the fruits turned slightly red. Harvesting was done at 7 days interval starting from 16th January 2022 and it was continued up to 5th February 2022.

Experimental data were recorded at harvesting stage. The data on growth and yield parameters were collected. The plant height (cm), plant girth (cm), number of fruits plant^{-1} (n), leaf length plant^{-1} (cm), and leaf width plant^{-1} (cm) as growth parameters were collected. The dry weight plant^{-1} (g), yield plant^{-1} (g), and harvest index of 3 treatments were calculated after harvesting. Stem anatomy of the plants growing under three different treatments was also performed at the laboratory of EXIM Bank Agricultural University, Bangladesh. Data were collected, compiled, and tabulated properly for statistical analysis. The recorded data were statistically analyzed to find out the significance of variation resulting from the experimental treatments. Collected data were analyzed using the "Analysis of Variance Technique" with the help of a computer package program Statistix 10. The analysis of profitability was performed considering only the variable production costs. Net Returns (NR) were calculated by deducting the overall total variable cost (TVC) of cultivation from gross returns (GR). The benefit-cost ratio (BCR) was calculated finally for measuring profitability. The method (BCR = GR/TVC)) used for calculating the BCR (Begum et al., 2019).

3. RESULTS

3.1 Growth and Yield Parameters

The growth and yield parameters of tomatoes, namely plant height, number of fruits plant^{-1}, and yield plant^{-1} were significantly impacted by the application of varying soil amounts (Table 1). However, plant girth, leaf length plant^{-1}, leaf width plant^{-1}, and dry weight plant^{-1} all showed statistically negligible but favorable effects of soil content (Table 1). The treatment T-3, which had the maximum soil content, produced the highest results for plant height (71.82 cm), plant girth (3.05 cm), number of fruits plant^{-1} (21.82), leaf length plant^{-1} (14.36 cm), leaf width plant^{-1} (10.95 cm), yield plant^{-1} (1176.4 g) and dry weight plant^{-1} (15.17 g). With decreased soil contained applied in treatment T-1, the lowest values were obtained for plant height (50.07 cm), plant girth (2.40 cm), number of fruits plant^{-1} (10.13), leaf length plant^{-1}

Table 1 Growth components of tomato (Number of sample = 54)

Treatment	Plant height (cm) $\bar{X}$ ± S.D.	Plant girth (cm) $\bar{X}$ ± S.D.	Number of fruits plant^{-1} $\bar{X}$ ± S.D.	Leaf length plant^{-1} (cm) $\bar{X}$ ± S.D.	Leaf width plant^{-1} (cm) $\bar{X}$ ± S.D.
T-1	50.07±5.86c	2.40 ±0.49b	10.13 ±3.18c	13.18±1.39b	10.44±1.35a
T-2	66.91±4.58b	2.93±0.67a	18.09±4.29b	13.95±1.41ab	10.83±1.30a
T-3	71.82 ±6.20a	3.05 ±0.48a	21.82 ±6.09a	14.36 ±1.57a	10.95 ±0.91a

$\bar{x}$, Mean value; SD, Standard deviation; in a column, means followed by a similar letter(s) were not significantly different whereas, means followed by a dissimilar letter(s) were significantly different.

(13.18 cm), leaf width plant^{-1} (10.44 cm), yield plant^{-1} (497.47 g), and dry weight plant^{-1} (9.23 g). The all parameters of the growth and yield in case of tomato significantly high in T-3 treatment from T-1 treatment studied here except the leaf width plant^{-1}. Some parameters were significant between T-3 and T-2 treatments (Table 1, Table 2, Fig. 1).

Fig. 1 Different growing stages of tomato in rooftop garden. A) Seedling stage after 15 days of transplantation, B) Flowering stage, C) Fruiting stage and D) Harvested fruits.

3.2 Harvest Index

According to the pie chart, treatment T-3 has the greatest harvest index (42%), followed by treatments T-1 (29%), and T-2 (29%), respectively (Fig. 2). This implies that tomato plants grown in treatments T-1 and T-2 were not as effective as plants grown in treatment T-3 at converting biomass into fruit.

3.3 Correlations of Parameters

The degrees of relationship among, plant height, plant girth, number of fruits plant^{-1}, leaf length plant^{-1} and leaf width plant^{-1} with yield plant^{-1} were analyzed. The relationship between plant height and yield is depicted in Fig. 3. The coefficient of correlation was 0.639 in 1%. The results demonstrated a considerably moderate positive association between plant height and yield (Fig. 3). The scattered dot from the fit line also exhibited a significant association in the graph. The independent variable plant height can account for 40.8% of the dependent variable yield (Fig. 4A).

Table 2 Yield components of tomato (Number of sample = 54)

Treatment	Yield plant^{-1} (g) $\bar{X}$ ± S.D.	Dry weight plant^{-1} (g) $\bar{X}$ ± S.D.
T-1	497.47±227.70c	9.23 ±3.12b
T-2	729.05±230.80b	13.49±2.02a
T-3	1176.4± 205.08a	15.17 ±3.73a

$\bar{x}$, Mean value; SD, Standard deviation; in a column, means followed by a similar letter(s) were not significantly different whereas, means followed by a dissimilar letter(s) were significantly different.

The relationship between plant girth and yield is depicted in Fig. 3. The correlation coefficient was 0.289 in 5%. The results demonstrated a substantial weak positive relationship between plant girth and yield that is significant. In the graph, the scattered dot from the fit line likewise shows a somewhat weak link. Only 8.4% of the dependent variable yield can be explained by the independent variable plant girth (Fig. 4B).

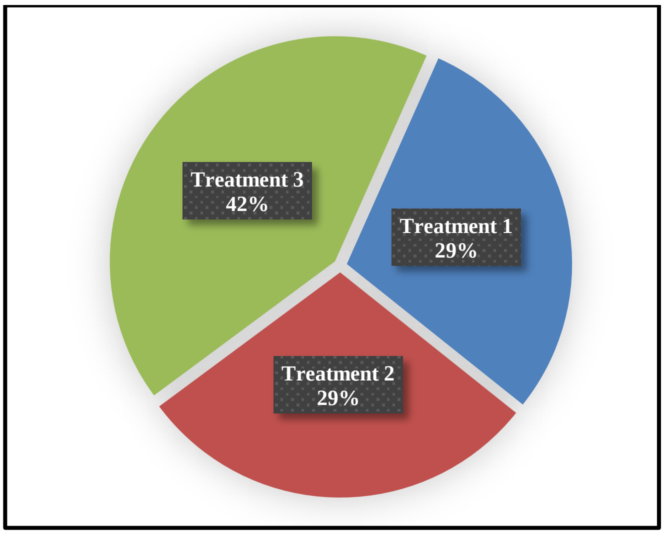

Fig. 2 Harvest index of tomato cultivation under T-1, T-2 and T-3 treatments on rooftop garden.

The correlation between numbers of fruits plant^{-1}and yield shown in Fig. 3. The result revealed that number of fruits plant^{-1}and yield have a positive (correlation coefficient 0.472 in 1%) and a moderate relationship that is significant. The dots are

Table: 3 Diameter of different cells in tomato stem (Number of sample = 50)

Treatment	Diameter of cortex (μm) $\bar{X}$ ± S.D.	Diameter of xylem (μm) $\bar{X}$ ± S.D.	Diameter of pith (μm) $\bar{X}$ ± S.D.
T-1	39.36 ± 7.16a	8.06 ± 2.60b	40.72 ± 24.60b
T-2	31.15 ± 9.92b	11.62 ± 2.13a	35.51± 21.44a
T-3	37.25 ± 9.82a	11.92 ± 2.05a	46.25 ± 15.30c

$\bar{x}$, Mean value; SD, Standard deviation; in a column, means followed by a similar letter(s) were not significantly different whereas, means followed by a dissimilar letter(s) were significantly different.

Table 4 Cost of rooftop tomato production

Particular	Tk	%
Total Variable Cost	735	100
Soil and soil preparation	300	40.82
Bags	165	22.45
Seedlings	50	6.80
Pesticides	120	16.33
Miscellaneous	100	13.60
Total Fixed Cost (Tk)		
Land Use	0	0
Total Cost (A+B)	735	100

Source: Cost Benefit Analysis (CBA) Method (Begum et al., 2019).

Table 5 Profitability of rooftop tomato production

Particular	Tomato
1. Total Fruit Yield (kg)	43.5
a. T-1 Yield (kg)	7.462
b. T-2 Yield (kg)	16.039
c. T-3 Yield (kg)	19.999
2. Price (Tk/kg)	30
3. Total variable cost (Tk)	735
4. Total cost (Tk)	735
5. Gross Return (main product) (Tk)	1305
6. Net Return (Tk)	570
BCR (Over total cost)	1.77

Source: Cost Benefit Analysis (CBA) Method (Begum et al., 2019).

dispersed around the fit line, suggesting a moderate correlation between yield and the number of fruits plant^{-1}. The dependent variable yield can be explained by 22.3% by the independent variable number of fruits plant^{-1} (Fig. 4C). The correlation between leaf length plant^{-1} and yield was shown in Fig. 3. The result revealed that leaf length plant^{-1} and yield have a positive (correlation coefficient, 0.433 in 1%) moderate relationship that is significant. The dots are placed scattered from the fit line indicating strong relationship between leaf length plant^{-1} and yield. The dependent variable yield can be explained 18.8% by independent variable leaf length plant^{-1} (Fig. 4D). The correlation between leaf width plant^{-1}and yields was shown in Fig. 3. The result revealed that leaf width plant^{-1}and yield have a positive (correlation coefficient, 0.352 in 1%) and weak relationship that is significant. The dots are placed scattered from the fit line indicating weak relationship of leaf width plant^{-1} and yield. The dependent variable yield can be explained 12.4% by independent variable leaf width plant^{-1} (Fig. 4E).

3.4 Stem Anatomy

Table 3 represents the average diameter of the tomato's cortex, xylem, and pith cell for each of the three soil volume treatments. The highest mean cortex cell diameter measured in T-1 was 39.36 μm; the next closest values were 37.25 μm in T-3 and 31.15 μm in T-2. In T-3, the maximum mean xylem diameter measured was 11.92 μm, while in T-2 and T-1, the values were 11.62 μm, and 8.06 μm, respectively (Table 3). In T-3, the maximum mean pith diameter measured was 46.25 μm, while in T-1 and T-2, the corresponding values were 40.72 μm and 35.51 μm. A high degree of variability is shown by the relatively high standard deviation for each of three tissues in each of the three treatments, as shown in Fig. 5.

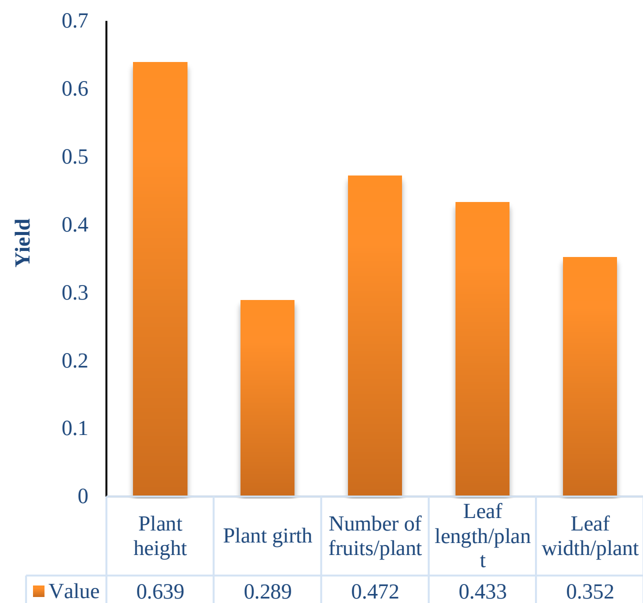

Fig. 3 Correlation of coefficient (r) value of five parameters with yield plant^{-1} of tomato.

3.5 Profitability Study

The average cost of production of tomato was estimated to be Tk. 735 in the present study. The total cost was only spent for variable cost, which was 735 Tk. The share of the total cost was found to be the highest for soil and soil preparation (40.82%) followed by bags (22.45%), pesticides (16.33%),

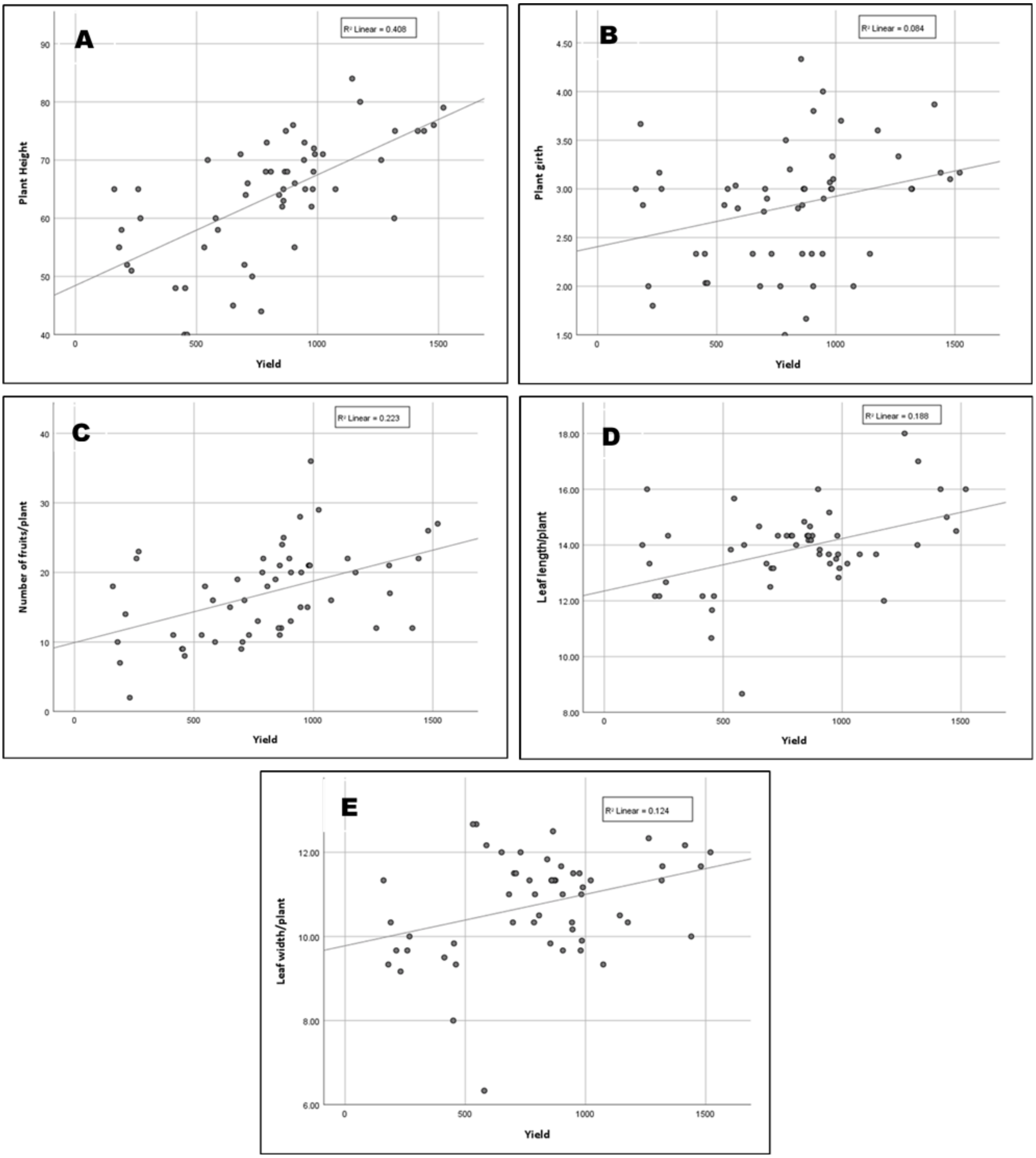

Fig. 4 Scattered diagrams of five parameters with yield. Relationship of yield with A) Plant height, B) Plant girth, C) Number of fruits plant^{-1}, D) Leaf length plant^{-1}, E) Leaf width plant^{-1}.

miscellaneous (13.60%) and seedlings (6.80%) among the cost items (Table 4). The average yield of tomato for T-1 was 7.462 kg, for T-2 was 16.039 kg and for T-3 was 19.999 kg (Table 5). The total average yield was 43.5 kg (Table 4). The gross return was Tk. 1305 while average net return of tomato was Tk. 570. The Benefit Cost Ratio (BCR) over total cost was 1.77 (Table 5). The result showed that the production of rooftop tomato was profitable.

4. DISCUSSION

The tomato c.v. Mintoo super was grown in six replications on 54 bags, with the plants varying in growth and yield characteristics. The plants that were subjected to the experiment showed variations in plant growth and yield parameters. All growth and yield parameters; plant height, plant girth, number of fruits plant^{-1}, leaf length plant^{-1}, leaf

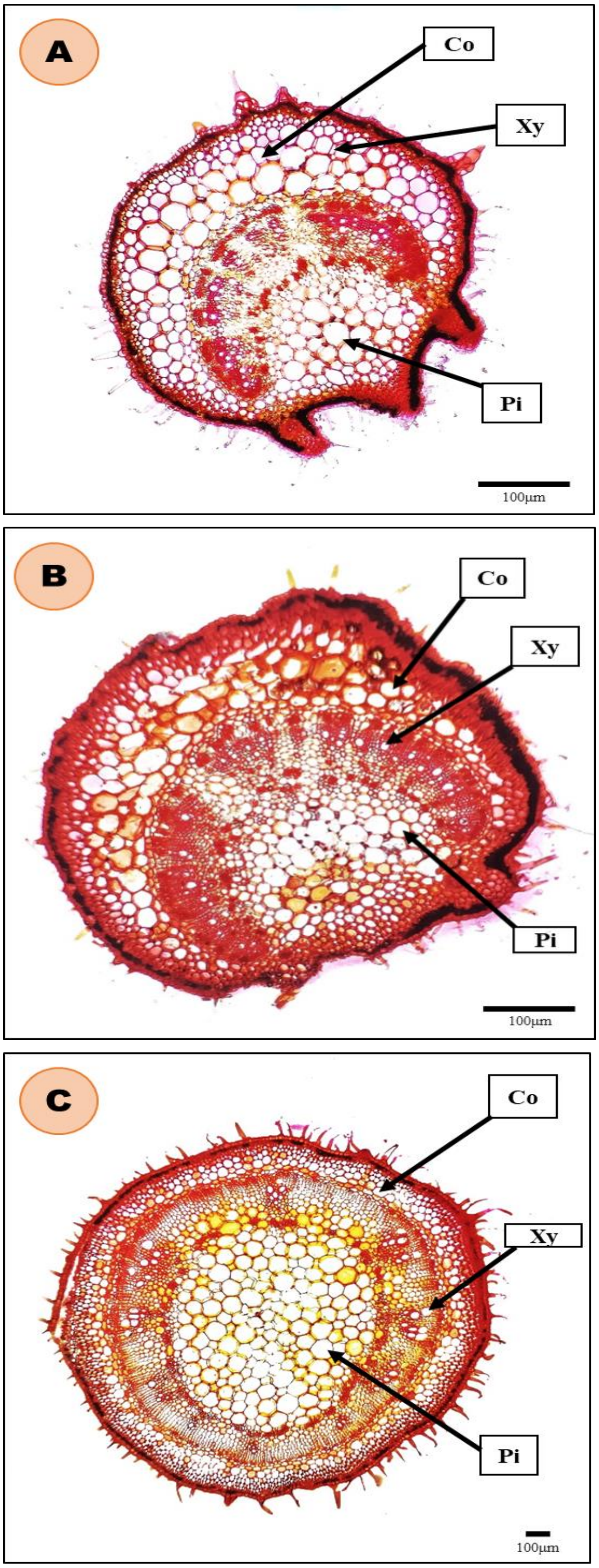

Fig. 5 Stem anatomy of *Solanum lycopersicum L.* A) Transverse section of stem of plant growing on T-1 treatment, B) Transverse section of stem of plant growing on T-2 treatment, C) Transverse section of stem of plant growing on T-3 treatment.

width plant^{-1}, yield plant^{-1} and dry weight plant^{-1} were highest in T-3 treatment, followed by T-2 and T-1. There was a reason for this, which was that T-3 had more soil quantity than the other treated bags, allowing for higher nutrient availability, water retention, and appropriate growth of roots. Bouzo & Favaro (2015) had shown that increasing the container size resulted in larger plants with greater precocity and production. Also, the physical restriction of root by the use of containers with low volumes severely limited the plant growth as well as yield.

Spomer et al. (1982) found direct relationship between container soil volume and plant growth, as demonstrated through a laboratory exercise. The study also discusses the impact of soil physical amendment on plant growth and the factors influencing growth differences in different soil volume treatments.

Wells & Postlethwaite (1970) found that soil volume had little effect on tomato crops when water and nutrients were supplied by capillary methods, with high yields obtained even from plots with a very small volume of soil per plant. However, there were some small significant reductions in yield at the lowest volume, likely due to nutrient availability and water supply limitations. Cornforth et al. (1968) found that increasing soil volume led to increased yields of oats, ryegrass, kale, and tomatoes, but decreased root intensity.

It also demonstrated that the accessibility of nutrients to roots is related to their mobility in soil. The harvest index was greatest in T-3 with larger soil quantity, followed by T-2 and T-1, respectively. Poorter et al. (2012) found meta-analysis of 65 studies, that doubling of pot size, on average, increased biomass production by 43%. While directly measuring harvest, index wasn't the primary focus, the increased biomass production in larger pots suggests potentially higher harvest index due to greater resource availability and root development. Anatomical aspects of the tomato stem showed variations. The average diameter of cortex, xylem, and pith cells varies in response to different treatments.

T-1 had bigger cortex cells, but T-3 had greater xylem and pith cell diameters. Angélico et al., (2021) showed that the influence of soil conditions on tree growth reflects variations in wood anatomical features. The BCR for rooftop tomato production was 1.77. This suggests that growing tomatoes on rooftops was profitable. It can benefit from a 77% profit in Bangladesh's northern area. Karim et al. (2009) studied the profitability of growing BARI Hybrid tomatoes over the summer in Bangladesh's Jessore district.

They employed net return and BCR to analyze profitability. They found that the yield of BARI hybrid tomatoes was 32.7 t/ha. The BCR was determined to be 4.19 on a full cost basis and 5.09 on a cash cost basis. Mohiuddin et al. (2007) investigated the adoption and profitability of improved tomato varieties in Chittagong, Bangladesh. Zaman et al. (2006) investigated the production potential of summer tomatoes in the Jamalpur area. They employed net return and BCR to analyze profitability. They discovered that the net return or profit for one hectare was Tk. 6,90,464 and the BCR was 3.2 in the research region.

5. CONCLUSION

This study examines how the quantity of soil affects tomato production in rooftop gardens. It demonstrates that tomato growth and yield are better in soil with larger quantity. Plant development was significantly impeded by the physical limitations imposed by the lowest size bags, however this effect reduced as the age of the plants. Furthermore, the impact of soil the quantity revealed physiological variations in anatomical aspects. Based on this study, we can recommend that for best output, tomato production in rooftop gardens should be done in a bit larger bag (15 kg). When considering the benefit-cost ratio, tomato production in a larger bag is advantageous for rooftop gardening. In summary, the findings provide support for the influence of soil the quantity on tomato growth and production and agree with previously published experimental studies.

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