International Journal of Environment and Climate Change

Volume 13, Issue 8, Page 1593-1605, 2023; Article no.IJECC.100628
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Growth and Yield Performance of Tomato (*Lycopersicum esculentum* L.) at Different Building Heights of Rooftop Gardening

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AH and MMBF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MGJH and MUH managed the analyses of the study. Authors TS and ZFBH managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i82109

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/100628

Original Research Article

Received: 27/03/2023
Accepted: 31/05/2023
Published: 14/06/2023

ABSTRACT

Rooftop gardening is very important for food security and environmental restoration, but if it is not economically feasible on the basis of productivity than rooftop gardening will not increase and sustain. To know the productivity at different heights of buildings roof, an experiment was conducted at the ground and the rooftop of different buildings at Sher-e-Bangla Agricultural University, Dhaka within a seven months period spanning through dry and rainy seasons. The experiment was laid out in a Completely Randomized Design with four replications containing four

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pots in each replicate. The plant material was BARI Tomato -14 and treatments of this experiment were T_1= Control (Ground level, 0.0 m), T_2= Rooftop of three storied building (11.28 m), T_3 = Rooftop of six storied building (21.34 m), T_4 = Rooftop of ten storied building (34.75 m). Different height of buildings rooftop showed significant effects on the air temperature, moisture of pot soil, growth, yield contributing characters and yield of tomato. The treatment T_1 showed significantly higher moisture content of pot soil, plant height, plant stem diameter, branch number per plant, leaf number per plant, flower cluster number per plant, fruit number per plant, fruit length, fruit diameter, individual fruit weight and yield per plant than all other treatments but T_4 showed significantly lowest results in all the above mentioned characters and Vice versa in case of air temperature. Growth and yield of tomato showed a gradually decreasing results with the increasing of buildings rooftop height. The sequence of growth and yield of tomato were T_1>T_2>T_3>T_4.

Keywords: Height; rooftop; temperature; moisture; yield.

1. INTRODUCTION

"Urbanization and Human Activities induced climate change impacts are two distinct hot topics that are worth discussing. Urbanization brings various challenges like greater ambient noises, increased environmental stressors and massive demand for food. 54% of the total world population is urbanized, the share is expected to reach up to 66% in less developed regions and 86% in most developed regions by 2050" [1]. "Moreover, many urban residents are facing problems due to lack of space for vegetation. Urban agriculture currently plays an important role in the global food system and studies have highlighted the potential for urban agriculture to contribute further to food security, food system resilience and sustainability" [2-4]. "Urban agriculture is the practice of cultivating, processing, and distributing food in or around urban areas. A roof garden is a garden on the roof of a building The practice of cultivating food on the rooftop of buildings is sometimes referred to as rooftop farming" [5]. "When rooftop garden of farm is situated in or around urban areas then it is also called urban agriculture. Limited space and competitive real-estate markets are impediments for in-ground agriculture, while farms retrofitted to roofs occupy otherwise underutilized space in the built environment" [6-8]. "The problem of urbanization and destruction of fertile soils invites the solution of rooftop gardening. Where the lives of people are obstructed and there is a scarcity of soil and land to cultivate plants, Rooftop gardening is itself a prodigious production pathway towards sustainability. With massive misuse of pesticide, degrading soil fertility and health hazards associated with consuming the market vegetables, there is the need to swiftly consider possible production alternatives. Rooftop gardening may seem a small step but it is a leap towards sustainability and combating the havoc of climate change hazards. Microclimate can be modified by rooftop farming because of its contribution to mitigate the ecological problems and advancement of metropolitan food system. Rooftop garden regulates the temperature on the roof as well as the room below the roof garden" [9]. "The temperature was reduced from 1.2 to 5.5% in different area coverages of agricultural roofs with plants compared to the nearest bare roofs. For the time being, the cooling load was decreased from 3.62 to 23.73%, and energy saving was increased significantly from 5.87 to 55.63% for agricultural roofs compared to bare roofs" [10].

"Bangladesh is a developing country and its economic growth is rapid and population growth also high. In Bangladesh, there is a total of 532 urban areas, which are divided into three categories. These are city corporation, municipal corporation (Pourasova) and upazila town. Among these urban areas, Dhaka is the largest city by population and area, with a population of 19.10 million" [11]. "There are total 11 city corporations and 329 municipal corporations and 203 small towns_in Bangladesh. According to 2011 population census, Bangladesh has about 28% urban population with a growth rate of 2.8%" [11]. At this growth rate, it is estimated that the urban population of Bangladesh will reach 79 million or 42% of total population by 2035.

With speedy and unplanned urbanization, incidence of city poverty and food shortage have been additionally growing and at an alarmingly in Dhaka [12]. Islam et al., [13] has recorded that urban agriculture (UA) contributes to meals protection [13]. "There are economic, social and environmental opportunities of local and efficient food production through innovative urban rooftop farming" [14]. "Bangladesh is one of the most densely populated countries in the world where 1015 persons are living per square kilometer" [15].

"In Bangladesh, rapid population growth has decreased the per-capita agricultural land: 0.11, 0.09, 0.07 and 0.06 ha/person in 1981, 1991, 2001 and 2011, respectively" [16]. "The increase in nuclear families and the division of land among family members, especially in the rural settlements of the country, is leading to agricultural land fragmentation, affecting total crop production" [17]. "The rapid rate of urbanisation is also affecting the change in land use and land cove, as more people are moving to urban areas and cultivated lands are being converted and used for non-agricultural purposes. It is estimated that the country is losing fertile agricultural land at a rate of approximately 80,000 ha annually due to rapid urbanisation, construction of new infrastructure such as roads and housing, and implementation of other development projects" [18]. "The current rate of urbanisation in Bangladesh is 3.3 percent growth per annum. Between 1976 and 2010, total agricultural land – including cropland, forest, mangrove, river, lake, beel (lake-like stagnant water body), haor (bowl-shaped shallow depression), aquaculture, tea estates and saltpans-decreased by 1.12 million ha" [19]. "During the same period, there has been an increase in non-agricultural land of 1.22 million ha" [16]. "According to the United Nations Population Fund's prediction, the population of Bangladesh may reach 201 million (under a low fertility rate scenario) or 245 million (under a high fertility rate scenario) by 2051" [20]. Due to urbanization and increase of population it is not possible to stop the decrease of arable land in Bangladesh. In this case, rooftop gardening can be a huge scope for production food which can contribute to food security.

Vegetables are one of the essential food items of daily requirement which can contribute in overcoming such health hazard. So, improvement of daily dietary value depends largely on the vegetable consumption. Approximately 1072000 acres of land have been cultivated with various vegetable crop varieties, with an annual production of 4336000 tons for the cropping year 2018-2019 [21]. The average consumption of vegetables is 75 g/day in Bangladesh whereas the recommended per capita vegetable consumption is 250 g/day accordingto Food and Agriculture Organization [22]. So, vegetable production and consumption need to be increased in Bangladesh. Vegetables are not produced evenly throughout the year in Bangladesh.

"Tomato (*Solanum lycopersicon* Mill.) is one of the most important edible and nutritious vegetable crops in Bangladesh. It is a member of solanaceae family. Tomato is a self crossing annual crop. Because of its well adaptability to broad range of soil and climate in Banglades, it is grown in all home garden and in the field condition also. It ranks next to potato and sweet potato in respect of vegetable production in the world. The cultivated area under tomato in Bangladesh is 6.81%, average yield 5451 kg/acre, total production 368000 tons" [23].

The environmental factors which are effected on production of tomato are temperature, moisture content of soil and light. Wu et al. (2015) revealed that, environmental factors temperature, light and soil moisture content effect the growth of tomato [24]. Plant development is strongly linked to temperature [25]. Even moderately high temperatures inhibit a number of reproductive processes in tomato and other species, resulting in poor fertilization and fruit set reviewed in [26]. Water had direct impact on tomato productivity [27]. But environmental factors (temperature and moisture content) may be different at different height of urban building.

Among the potential vegetables, tomato is a very popular vegetable in Bangladesh. Unfortunately, this crop has not been studied on rooftop gardening at different height of buildings rooftop. Considering the above-mentioned facts, a popular tomato variety was selected in this study for evaluating the performance of growth and yield of tomato on different height of buildings rooftop.

The research work had the following objectives:

1. To evaluate temperature of air the and moisture of pot soil at different height of buildings rooftop.
2. To evaluate the growth and yield contributing characters of tomato at different height of buildings rooftop.
3. To identify the optimum height of building rooftop for tomato cultivation.

2. MATERIALS AND METHODS

Location: The experimental site was located between 23°74/N latitude and 90°35/E longitudes with an altitude of 8.2 m, Sher-e-Bangla Agricultural University, Bangladesh.

Plant materials: Tomato (BARI Tomato -14)

Treatments: The following four treatments were maintained in this study-

T_1 -control (ground) (0.0 m)
T_2-rooftop of three storied building (11.28 m)
T_3- rooftop of six storied building (21.34 m)
T_4- rooftop of ten storied building (34.75 m)

Experimental Design and Layout: The experiment was laid out in a completely Randomized Design (CRD) with four replications on ground and different height of three buildings rooftop in plastic pot contained four pots in each replication and each pot contained 1 tomato plant.

Uprooting and Transplanting of Seedlings: Seedlings of 35 days old were uprooted separately from the seedbed and transplanted properly.

Intercultural Operations: Intercultural operations were done whenever needed for better growth and development. Intercultural operations followed in the experiment were irrigation, weeding, staking, pest control etc.

Harvesting: Harvesting was started during early ripe stage when the fruits attained slightly red color. Harvesting was done at 7 days' interval starting from 15th February, 2022 and was continued up to 15th March, 2022.

Data Collection and Recording: Experimental data were recorded from 15 days after transplanting and continued until last harvest. The following data were recorded during the experimental period.

1. **Temperature:** The temperature of air was taken by the help of Thermometer at 30 DAT, 40 DAT, 50 DAT, 60 DAT at day (2.0 pm) and night (10.0 pm). The temperature was taken in degree Celsius (^{0}C).
2. **Moisture of Pot Soil:** The moisture content of the pot soil was taken consecutively 7 days from 45 DAT to 51 DAT by the help of Moisture meter at 4.0 pm and average moisture content was calculated. The moisture was taken in %.
3. **Plant Height:** Plant height was measured in centimeter from the ground level to the tip of the highest leaf and means value was calculated. To observe the growth rate plant height was recorded at 15 DAT, 30 DAT, 45 DAT and 60 DAT (days after transplanting).
4. **Plant Stem Diameter:** Plant stem diameter was measured in centimeter by using Vernier caliper. Stem diameter was recorded at 15 DAT, 30 DAT, 45 DAT and 60 DAT.
5. **Number of Leaves per Plant:** Leaves number were counted from each plant at 15 DAT, 30 DAT, 45 DAT and 60 DAT.
6. **Number of Branches per Plant:** The total number of branches per plant were counted from each plant at 15 DAT, 30 DAT, 45 DAT and 60 DAT.
7. **Chlorophyll Content:** Chlorophyll content of the leaves of plant was measured by SPAD-meter. Unit of chlorophyll content was SPAD value.
8. **Flower Cluster Number per Plant:** Total number of flower cluster per plant were counted and recorded.
9. **Number of Fruits per Plant:** Total number of fruits per plant were counted and recorded.
10. **Fruit Length:** The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of randomly selected 6 fruits in centimeter (cm) and calculated the average length of the fruit.
11. **Fruit Diameter:** Diameter of fruit was measured at the middle portion of randomly selected 6 fruits from each plant with a slide calipers in centimeter (cm) and calculated the average diameter of the fruit.
12. **Individual Fruit Weight:** Total weight of fruit was measured from each plant from 1st to last harvest and individual fruit weight was measured divided with the number of fruits per plant. Individual fruit weight was recorded in gram (g).
13. **Fruit Yield per Plant:** Fruit yield per plant was calculated by totaling fruit yield from first to final harvest and was recorded in gram (g).

Statistical Analysis: All the obtained data were subjected to compiled and analyzed by microsoft Excel Worksheet and Statistix 10 software.

3. RESULTS AND DISCUSSION

Results obtained from the study have been presented and discussed in this section with a view to evaluation the air temperature and soil moisture and then performance of tomato growth, yield contributing characters and yield on different height of buildings rooftop to compare with ground level. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

3.1 Air Temperature

Fig. 1 showed that, during day and night, there were significant differences of air temperature among T_1, T_2, T_3, T_4. The lowest temperature was found at T_1 and the highest temperature was found at T_4. T_3 which showed comparatively higher temperature than T_2. The temperature was increased with the increased of building rooftop height. The sequence of day temperature was $T_4>T_3>T_2>T_1$.

3.2 Moisture Content of Pot Soil

Moisture content of pot soil at T_1 showed higher than T_2, T_3 and T_4 but T_4 showed lowest moisture content. T_2 was statistically similar with T_3 but significantly higher than T_4. On the other hand, T_3 had statistically similar moisture content with T_4 (Fig. 2).

3.3 Plant Height

At 15 DAT, 30 DAT, 45 DAT and 60 DAT, the highest plant height was found in T_1. Plant height of T_1 was significantly higher than T_2, T_3 and T_4. The lowest plant height showed T_4 compared T_1, T_2, T_3. T_2 and T_3 were significantly higher than T_4 and T_2 was significantly higher than T_3 (Table 1). At 15 DAT, 30 DAT, 45 DAT and 60 DAT, plant height showed a decreasing sequence with the increasing of building rooftop height. The sequence of plant height was $T_1>T_2>T_3>T_4$ (Table 1). As building rooftop height increased, as well as air temperature increased but moisture content of pot soil decreased which adversely affected on plant height. High temperature condition strongly affected the vegetative organs and tissues of tomato plants for all cultivars [28]. Sibomana et al*.* revealed that, Severe water stress (40% of PC) reduced the plant height by 24% compared to the control [29].

3.4 Plant Stem Diameter

At 15 DAT, 30 DAT, 45 DAT and 60 DAT, the highest plant stem diameter was found in T_1. Stem diameter of T_1 was significantly higher at 95% confidence level than T_2, T_3 and T_4. The lowest stem diameter was found in T_4.

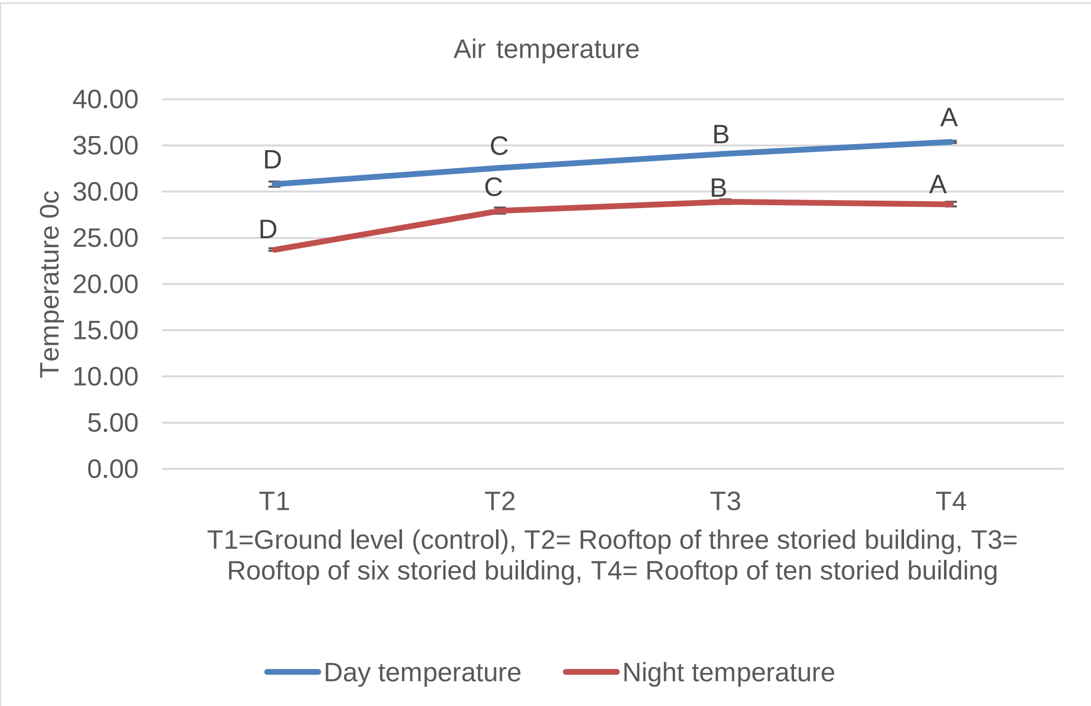

Fig. 1. Day and Night air temperature at different building height of rooftop garden

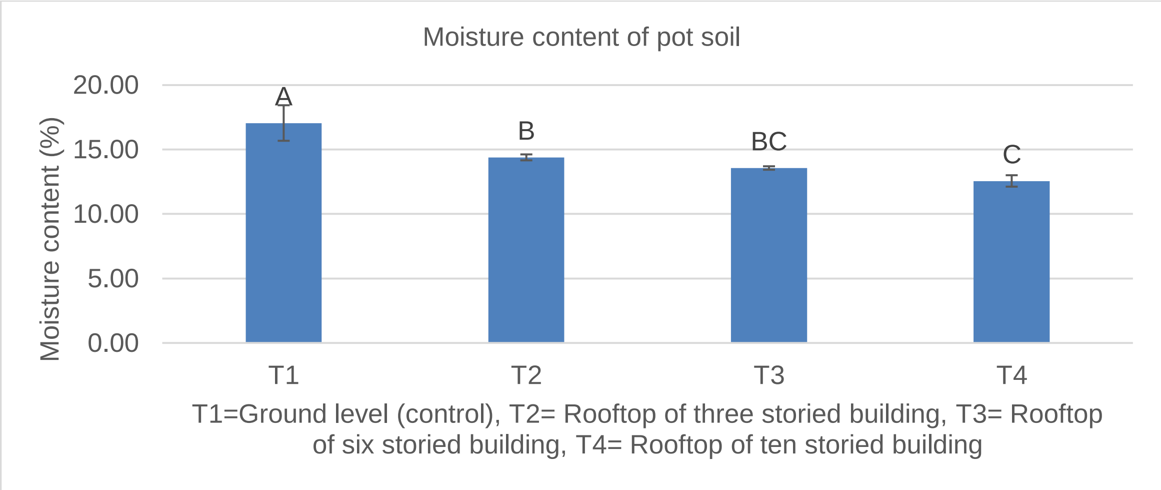

Fig. 2. Moisture content of pot soil at different building height of rooftop garden

Table 1. Plant height of tomato at different building height of rooftop garden at different days after transplanting

Treatment	Plant Height (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
T_1	16.72 A	39.35 A	67.12 A	89.26 A
T_2	14.18 B	31.59 B	52.49 B	78.60 B
T_3	13.72 C	27.70 C	45.51 C	62.59 C
T_4	11.09 D	23.58 D	42.28 D	54.72 D
CV%	1.5	2.23	1.42	1.07
LSD (0.05)				

DAT=Days After transplanting, T1=Ground level (control), T2=Rooftop of three storied building, T3= Rooftop of six storied building, T4= Rooftop of ten storied building, LSD= least significant difference. In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

At 15 DAT, 30 DAT, 45 DAT and 60 DAT, stem diameter showed a decreasing sequence with the increasing of building rooftop height. The sequence of stem diameter was $T_1>T_2>T_3>T_4$ (Table 2). Increasing of building rooftop height, caused increasing of air temperature but decreasing of moisture content of pot soil occurred that causes decreased stem diameter of tomato plant stem. Sibomana et al. revealed that, Severe water stress (40% of PC) reduced the stem diameter by 18% compared to the control [29].

Table 2. Stem diameter of tomato at different building height of rooftop garden at different days after transplanting

Treatment	Plant Diameter (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
T_1	0.66 A	1.01 A	1.26 A	1.47 A
T_2	0.51 B	0.78 B	1.00 B	1.20 B
T_3	0.46 C	0.71 C	0.94 C	1.02 C
T_4	0.41 D	0.66 D	0.84 D	0.94 D
CV%	1.81	1.10	1.60	1.60
LSD (0.05)				

DAT=Days After transplanting, T1=Ground level (control), T2=Rooftop of three storied building, T3= Rooftop of six storied building, T4= Rooftop of ten storied building, LSD= least significant difference. In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

3.5 Leaf Number per Plant

At 15 DAT, the highest leaf number per plant was found at T_1 which was significantly higher than all other treatments (T_2, T_3 and T_4) and the lowest leaf number per plant was found at T_4. The leaf number at T_2 (4.75) was statistically similar to T_3 (4.56) but higher than T_4 (Table 3).

At 30 DAT, 45 DAT and 60 DAT, the highest leaf number per plant was found at T_1 and the lowest leaf number per plant was found at T_4. The leaf number per plant of T_2 was higher than T_3. At 30 DAT, 45 DAT and 60 DAT, leaf number per plant showed a decreasing sequence with the increasing of building rooftop height. The sequence of leaf number per plant was T_1>T_2>T_3>T_4 at 30 DAT (Table 3). High air temperature and low soil moisture occurred due to increased building rooftop height and tomato leaf number decreased. Soil moisture affected the vegetative growth stage of tomato [30]. Sibomana et al. [29] revealed that, water stress resulted in significant decreases in vegetative growth [29].

3.6 Branch Number per Plant

At 30 DAT, the highest branch number per plant was found at T_1 which was significantly higher than T_3 and T_4 but T_1 was statistically similar with T_2. The branch number per plant of T_2 and T_3 were found 6.38 and 5.88 respectively which were statistically similar but higher than T_4 (Table 4). The lowest branch number per plant was found at T_4 which was 4.81.

At 45 DAT, the highest branch number per plant was found at T_1 (9.81) which was significantly higher than T_2, T_3 and T_4. The lowest branch number per plant was found at T_4 (6.63). The branch number per plant of T_3 and T_4 were 7.13 and 6.63 respectively which were statistically similar. Branch number per plant at T_2 was statistically higher than T_3 and T_4 (Table 4).

Table 3. Leaf number per plant of tomato at different building height of rooftop garden at different days after transplanting

Treatment	Leaf Number			
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**
T_1	5.63 A	25.88 A	33.13 A	49.66 A
T_2	4.75 B	18.69 B	28.81 B	39.06 B
T_3	4.56 B	15.78 C	23.68 C	34.73 C
T_4	4.00 C	11.48 D	20.84 D	29.63 D
CV%	5.23	4.45	2.8	2.64
LSD (0.05)				

DAT=Days After transplanting, T1=Ground level (control), T2=Rooftop of three storied building, T3= Rooftop of six storied building, T4= Rooftop of ten storied building, LSD= least significant difference. In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 4. Branch number per plant of tomato at different building height of rooftop garden at different days after transplanting

Treatment	Branch Number		
	30 DAT	**45 DAT**	**60 DAT**
T_1	7.13 A	9.81 A	11.00 A
T_2	6.38 AB	7.94 B	9.50 B
T_3	5.88 B	7.13 C	8.81 C
T_4	4.81 C	6.63 C	7.25 D
CV%	6.51	4.81	3.42
LSD (0.05)			

DAT=Days After transplanting, T1=Ground level (control), T2=Rooftop of three storied building, T3= Rooftop of six storied building, T4= Rooftop of ten storied building, LSD= least significant difference. In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

At 60 DAT, the highest branch number per plant was found at T_1 which was significantly higher than T_2, T_3 and T_4. The lowest branch number per plant was found at T_4. T_2 produced higher branch per plant than then T_3 and T_4. At 60 DAT, branch number per plant showed a decreasing sequence with the increasing of building rooftop height. The sequence of branch number per plant was $T_1>T_2>T_3>T_4$ at 60 DAT (Table 4). High air temperature and low moisture content of pot soil occurred due to increased building rooftop height that affected the branch number of tomato plant. Abdalla and Verkerk [31], Abdul-Baki [32], Peet et al. [33] and El Ahamdi and Stevens [34] revealed the adverse effect of high temperature on the vegetative development in tomato plants.

3.7 Chlorophyll Content of Tomato Leaf

There was no significant difference among these treatments (T_1, T_2, T_3 and T_4) for SPAD value of tomato leaf (Fig. 3). Amount of chlorophyll in leaf tissue is influenced by nutrient availability and environmental stresses such as drought, salinity, cold and heat etc. [35] but due to same nutrient, soil pH, light and not extreme or drought condition of soil chlorophyll content was not affected significantly at different building height of rooftop garden.

3.8 Number of Flower Cluster per Plant

Fig. 4 revealed that, the highest number for flower cluster per plant was found in T_1 and the lowest number of flower cluster per plant was found in T_4. T_2 produced statistically similar number of flower cluster per plant with T_3 but significantly higher than T_4. High air temperature and low soil moisture also affected on reproductive organs like number of flower cluster per plant and high air temperature and low moisture content of soil occurred due to building rooftop height increased. High temperature condition strongly affected the reproductive organs and tissues of tomato plants for all cultivars [28]. Tomato was effected by soil moisture during flower setting stage [30]. Tomato plants drop flowers when exposed to several days of daytime temperature above 29°C and nighttime temperature above 21°C [36]. Abdalla and Verkerk [31], Abdul-Baki [32], Peet et al. [33] and El Ahamdi and Stevens [34] revealed the adverse effect of high temperature on the reproductive development in tomato plants and under a high temperature condition leading to flower drop.

3.9 Number of Fruits per Plant

For number of fruits per plant, T_1 was statistically higher than T_2, T_3 and T_4 and T_4 was significantly lower than all other treatments. T_2 produced higher fruit per plant than T_3 and T_3 produced higher fruit per plant than T_4. Fruit number per plant showed a decreasing result with the increasing of building rooftop height. The sequence of fruit number per plant was $T_1>T_2>T_3>T_4$ (Fig. 5). High air temperature and low soil moisture occurred due to increase building rooftop height that adversely affected on number of fruits per plants The soil moisture content lower than 65% of filed capacity also decreased the fruit number [37]. Tomato was effected by soil moisture during fruit setting stage [30]. Abdalla and Verkerk [31], Abdul-Baki [32], Peet et al. [33] and El Ahamdi and Stevens [34] revealed the adverse effect of high temperature on the reproductive development in tomato plants and under a high temperature condition, the fertility rate of tomato flowers is greatly reduced and reduced fruit setting.

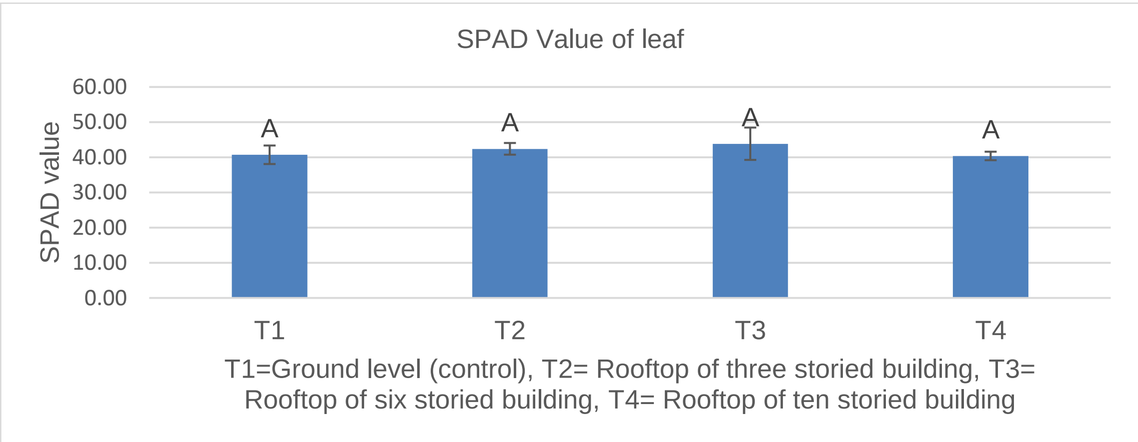

Fig. 3. SPAD value of tomato at different building height of rooftop garden

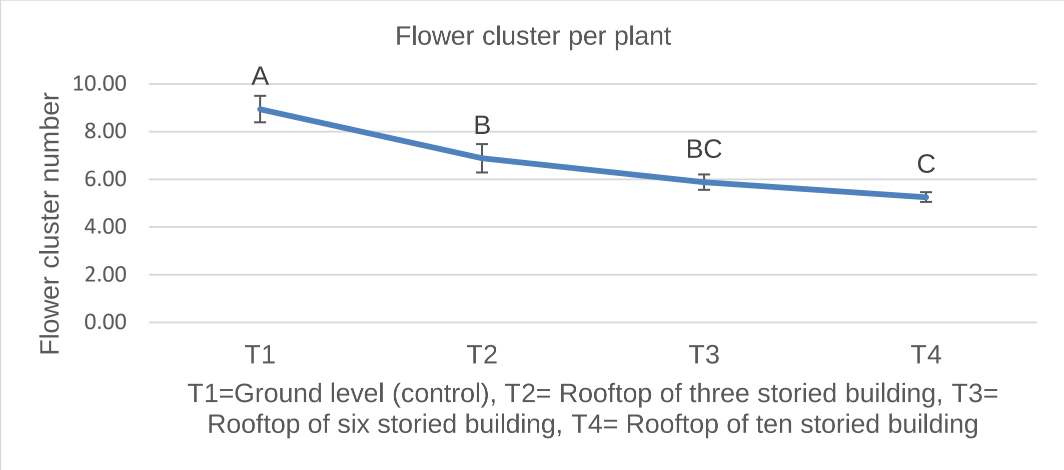

Fig. 4. Flower cluster number per plant of tomato at different building height of rooftop garden

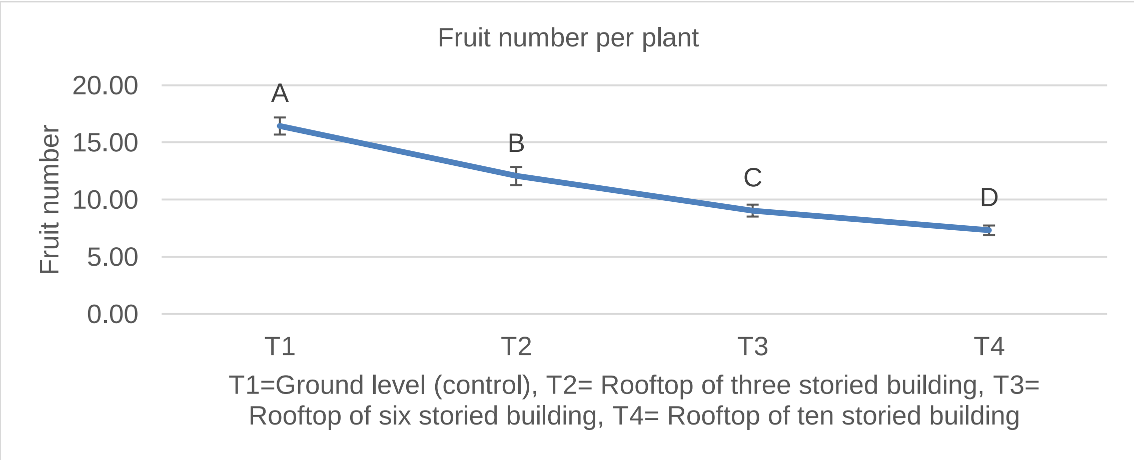

Fig. 5. Fruit number per plant of tomato at different building height of rooftop garden

3.10 Individual Fruit Length

The highest fruit length was found at T_1 which was statistically higher than T_2, T_3 and T_4. The lowest fruit length was found at T_4. T_2 was higher than T_3. But fruit length at T_3 and T_4 was statistically similar (Fig. 6).

3.11 Individual Fruit Diameter

The highest fruit diameter was found at T_1 and the lowest fruit diameter was found at T_4. Fruit diameter showed at T_1 was higher than T_2, T_3 and T_4. T_2 was statistically higher than T_3. Fruit diameter at T_3 and T_4 showed statistically similar result (Fig. 7).

3.12 Individual Fruit Weight

Table 5 showed that, the highest individual fruit weight was found at T_1 which was 98.32 g and the lowest individual fruit weight was found at T_4 which was 52.61 g. Individual Fruit weight at T_2 and T_3 was 80.65 g and 64.23 g respectively in which T_2 was statistically higher than T_3. Individual fruit weight showed a decreasing result with the increasing of building rooftop height. The sequence of individual fruit weight was $T_1>T_2>T_3>T_4$. As building rooftop height increased, as well as air temperature increased but moisture content of pot soil decreased which adversely affected on individual fruit weight. Elevating the temperature often increases the fruit growth rate, but it has a greater effect in hastening maturity and, as a result, the final mean weight of tomato fruits is reduced [38]. Tomato yield as effected by soil moisture during fruit development stage [30].

3.13 Total Fruit Yield per Plant

Highest fruit yield per plant was found at T_1 which was significantly higher than T_2, T_3 and T_4.

Total fruit yield per plant showed significant differences among T_1, T_2, T_3 and T_4. The highest fruit yield per plant was found at T_1 which was 1664.9 g and the lowest fruit yield was found at T_4 which was 401.24 g. T_2 produced significantly higher fruit yield per plant than T_3. The yield of T_2 and T_3 was found 992.31 g and 612.89 g respectively. Fruit yield per plant showed a decreasing result with the increasing of building rooftop height. The sequence of fruit yield per plant was T_1>T_2>T_3>T_4 (Table 5). High air temperature and low soil moisture also affected on reproductive organs that affect the yield of tomato and high air temperature and low moisture content of soil occurred due to building rooftop height increased. High temperatures

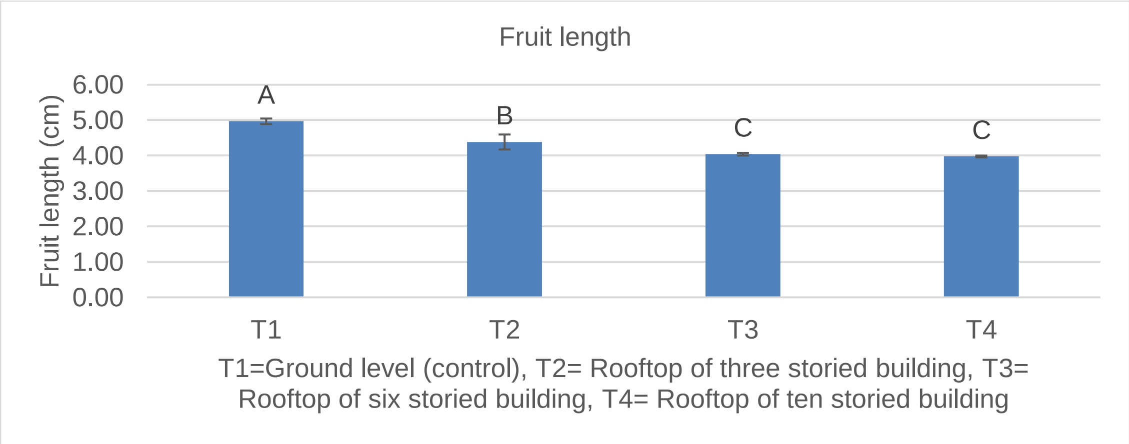

Fig. 6. Individual fruit length of tomato at different building height of rooftop garden

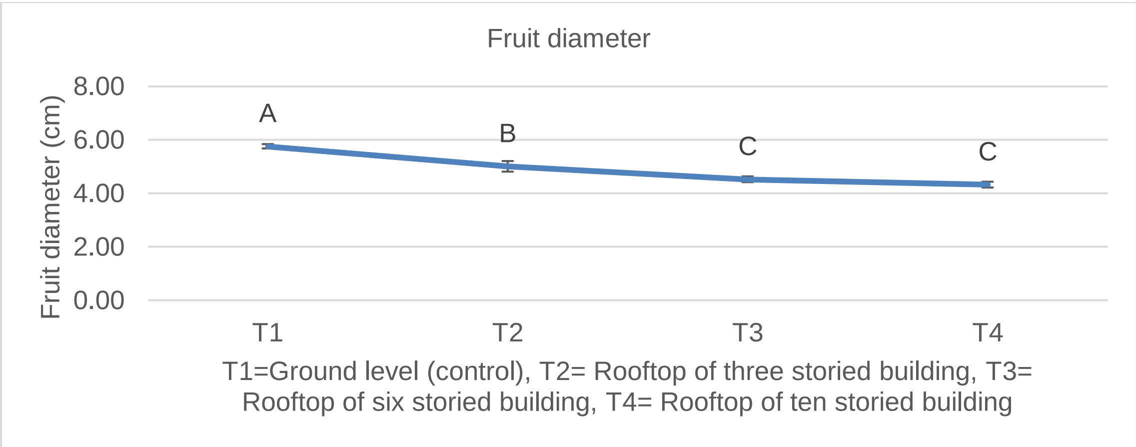

Fig. 7. Individual fruit diameter of tomato at different building height of rooftop garden

Table 5. Individual fruit weight and yield of tomato per plant at different building height of rooftop garden

Treatment	Individual Fruit Weight (g)	Total Fruit Yield per Plant (g)
T_1	98.32 A	1664.9 A
T_2	80.65 B	992.31 B
T_3	64.23 C	612.89 C
T_4	52.62 D	401.24 D
CV%	2.21	2.20
LSD (0.05)		

T1=Ground level (control), T2=Rooftop of three storied building, T3= Rooftop of six storied building, T4= Rooftop of ten storied building, LSD= least significant difference. . In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability affect several physiological and biochemical processes dealing finally with yield reduction [39]. The soil moisture content lower than 65% of filed capacity also decreased the yield by decreasing fruit number and increasing the formation of small and malformed [37]. Tomato yield as effected by soil moisture during fruit maturity stage [30]. Tomato reproduction is severely affected at day temperatures above 35°C. As a result, tomato yield decreased by 52% to 85% at high air temperatures. Yield reduction under high temperature was primarily due to lower fruit production [36].

4. CONCLUSION

Different height of building rooftop showed significant effect on vegetative growth of tomato, temperature of air at day and night, moisture content of pot soil, yield contributing characters and yield of tomato. The treatment T_1 (ground level) showed significantly higher plant height, plant stem diameter, branch number per plant, leaf number per plant, flower cluster number per plant, fruit number per plant, fruit length, fruit diameter, individual fruit weight and yield per plant than all other treatments but T_4 (ten storied building rooftop) showed significantly lowest result in all the above mentioned characters. T_1 showed lowest result in case of air temperature at day and night but T_4 showed highest result. In case of moisture content of pot soil, T_1 showed highest but T_4 showed lowest result. There was no significant effect on chlorophyll content of leaf of tomato. All the growth, yield and yield contributing characters except chlorophyll content showed a gradually decreasing results with the increasing of height of building rooftop. The sequence of growth, moisture content of pot soil, yield contributing characters and yield were $T_1>T_2>T_3>T_4$ but in case of air temperature, the sequence was $T_4> T_3> T_2> T_1$.

Tomato plant produced higher growth and yield in T_1 (Ground level) than T_2, T_3 and T_4 treatment. So it is concluded that, T_1 treatment showed optimum performance in case of vegetative growth and maximum yield of tomato than the other treatment. But among rooftop gardening, T_2 (three storied building rooftop) showed highest performance incase growth, yield and yield contributing characters. As gradually increased the height of building rooftop, sequentially decreased the growth, yield and yield contributing characters ($T_2>T_3>T_4$).

ACKNOWLEDGEMENTS

Sher-e-Bangla Agricultural University Research System provided funding for this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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