Original Research Article

Growth and Yield Performance of Chili (*Capsicum annuum* L.) on Rooftop of Different Height of Buildings

ABSTRACT

In urban agriculture, rooftop gardening is a remarkable part which is practiced to overcome the food crisis and climate change; if it is not economically viable on the basis of productivity, then rooftop garden will not enhance and sustain. So, a pot experiment was conducted during November 2021 to April 2022 on the rooftop of different height of buildings and Agroforestry research field at Sher-e-Bangla Agricultural University, Dhaka-1207 to study the productivity of chili (BARI Morich 3). The experiment was laid out in a Completely Randomized Design with four replications. The treatments of this experiment were 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) and T_4 = Rooftop of ten storied building (34.75 m). Results indicated that soil moisture content, plant height, stem diameter, number of (leaf, branch and fruit), fresh and dry weight of plant, single fruit (weight, length and diameter), fresh and dry weight of yield per plant were significantly decreased with the increased of building height (T_1>T_2>T_3>T_4) and air temperature, soil temperature and light intensity were significantly increased with the increased of building height (T_4> T_3> T_2> T_1).As gradually increased the height of building rooftop, sequentially decreased the growth, yield and yield contributing characteristics of chili plant. Although ground performed the best productivity, up to rooftop of three storied building can be selected as an appropriate height for chili (BARI Morich-3) cultivation to increase the rooftop gardening.

Keywords: Rooftop; B~~b~~uilding H~~h~~eight; ~~t~~Temperature; ~~m~~Moisture; L~~l~~ight ~~i~~Intensity; ~~g~~Growth; ~~y~~Yield

1. INTRODUCTION

Bangladesh is recognized as one of the vulnerable country which is facing many problems related to crop production, food scarcity, poverty etc due to adverse impact of climate change. In Bangladesh, there are total 543 urban areas (11 city corporations, 329 municipal corporations and 203 U~~u~~pazila towns). Among these urban areas, Dhaka is the largest city by population and area, with a population of 19.10 million [1]. According to 2011 population census, Bangladesh has an urban population of 28%, with a growth rate of 2.8% [2]. At this growth rate, it is estimated that the urban population of Bangladesh will reach 79 million or 42% of total population by 2035. It has been reported that urban agriculture has most important contribution to meet the food demand as well as help to improve surrounding environment. Due to the fastest growth and development of urbanization, this process is also placing a great demand of food supply systems in the urban areas. Rooftop gardening is an important part of urban agriculture to grow different vegetables and fruits on the building roof. For this reason, urban agriculture or rooftop gardening is promoted as a potential solution to minimize this entire problem [3].

Rooftop gardening can be an effective method for ensuring food supply and satisfying nutritional needs of the inhabitants. As a part of urban vegetation, rooftop garden systems improve air quality and decrease urban temperature, extend roof life, reduce energy use, increase property value, pleasing work environment, increased ecological benefits (biodiversity) and economic benefits (source of crop production) etc. [4-5], including storm water management, energy conservation, mitigation of the urban heat island effect, increased longevity of roofing membranes, also provide a more aesthetically pleasing environment in which to work and live [6].

Rooftop gardening has additionally a promising plausible for small-scale enterprise that can speed up extra household income. Nevertheless, it may additionally generate some employment services via its backward and ahead linkages. The manufacturing of clean fruits and greens from the rooftop backyard can be multiplied dietary fame for family contributors of the city residents and it will make a high-quality contribution to the environment. Sajjaduzzaman (2005)) [7] said that the most important reason of roof gardening is passing amusement time (100%), growing aesthetic values (100%), contributing in environmental amelioration (45%) and economic reap being a very minor subject (4% only) in Dhaka Metropolitan metropolis of Bangladesh.

Rooftop farming help to reduce the temperature of roofs and the surrounding air that contribute to overall cooling a local climate [8] and which also help to lessen urban heat island effect [4]. Rooftop farming can also help to absorb carbon emissions and noise [9]. Rain water is captured and absorbed by the plants and overflowing effect on infrastructure is also reduced [8].

Chili (*Capsicum annuum* L.) belongs to the nightshade family, Solanaceae which is originated from South America; the name comes from Nahuat via the Spanish word chili. Chili is an important spice crop in Bangladesh. Chilies are the fruits or berries of plants which belonging to the genus *Capsicum* under the family, Solanaceae. Chili is one of the most important domesticated spices in Bangladesh. It is grown throughout the year and used as green and dry stages for their pungency and color [10]. It is also a cash crop of the country [11]. In Bangladesh, chili crops occupies 103.24 thousand hectare of land with a production of 137 thousand metric tons [12].

Chili is an excellent source of vitamin A and C. Being richest source of vitamin C, it is sometimes referred as capsule of vitamin C [13]. The pungency in chili is due to an alkaloid capsaicin ($C_9Hi_4O_2$) which is a digestive stimulant. It contains high nutritive value with 1.29 mg/100 g protein, 11 mg/100 g calcium, 870 I.U vitamins-A, 175 mg ascorbic acid, 0.06 mg thiamine, 0.03 mg riboflavin, 0.55 niacin per 100 g edible fruit and 321mg per 100 g of vitamin C [10]. They have beta carotene which is as much as that found in spinach of 180 mg per 100 g [14].

In the majority of cases, growth & yield performance of different vegetable crops in rooftop gardening depends on environmental factors (temperature, moisture content, light intensity, humidity etc). Fahim et al. (2023)) [15], revealed that environmental factors (temperature at day & night and soil moisture content) effect the growth and yield of vegetable (tomato). High temperatures and low moisture condition inhibit the growth and production of chili [16], resulting in poor fertilization and fruit set reviewed in [17]. Development of plant is highly linked to temperature [18]. But in urban areas, the environmental factors (temperature, moisture, light intensity, humidity etc.) may be different on rooftop of different height of building.

Chili is a highly well-liked vegetable in Bangladesh among the probable vegetables. Unfortunately, not enough research has been done to determine how different building heights affect the growth and production of chili. In light of the aforementioned information, a well-known chili variety was chosen for this study's aim of analyzing the growth and yield performance of chili on rooftops of various building heights. Considering the above-mentioned facts, a famous chili variety was selected in this study to determine the growth & yield performance of chili on rooftop of different building height with the following objectives:

- **i.** To evaluate the growth and yield contributing characteristics and yield of chilion rooftop of different height of buildings.
- **ii.** To determine the air temperature, soil temperature, soil moisture and light intensity on rooftop of different height of buildings.
- **iii.** To select the optimum height of building for chili production in rooftop gardening.

2. MATERIALS AND METHODS

2.1 Location of the Experiment: The experiment was conducted on the roofs of different buildings and Agroforestry research field between 23°74/N latitude and 90°35/E longitudes with an altitude of 8.2 m, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

2.2 Plant M~~m~~aterial: BARI Morich-3

2.3 Treatments of the R~~r~~eplications

Rooftop of different height of buildings and ground level were used in the experiment.

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)

2.4 Experimental D~~d~~esign and ~~l~~Layout:

The experiment was laid out in a Completely Randomized Design (CRD). It was carried out in pots of 14 cm^2 top surface area. Four replications (4 plots in ground and 12 rooftops of different building) were maintained for each treatment. Each replication contained four pots and each pot contained one seedling.

2.5 Raising of S~~s~~eedlings

On November 15th, 2021, seeds were sown in the pot, and 50g of furadan was used as an insecticide. 5-8 days after sowing, the seedlings were emerged. For illness prevention, diathane M-45 was sprayed in the pot @ 2g/l. The appropriate amount of irrigation, mulching, and weeding was done.

2.6 Pot P~~p~~reparation, Manure and F~~f~~ertilizer ~~a~~Application

Ten days before to seedling transplantation, plastic pots were filled with weed-free soil and fertilised with cow dung, urea, TSP, and MP for nitrogen, phosphorous, and potassium. The final pot soil was made using 318 kg of cow dung, 320 g of TSP, and 1/4 of 256 g of urea. The remaining 192 g of urea and 192 g of MP were consumed at a rate of 3 g/pot over three portions.

2.7 Uprooting and Transplanting of S~~s~~eedlings

Seedlings of 35 days old on 21th December 2021 were uprooted separately from the pot and transplanted properly.

2.8 Intercultural O~~o~~perations

Intercultural operations were done whenever needed for better growth and development. Intercultural operations followed in the experiment were:

2.8.1 **Irrigation:**Irrigation was provided once a day on the basis of need to the pots of ground level. Same amount of water was provided to all the pots.

2.8.2 **Weeding:**Weeding was done whenever it was necessary, mostly in vegetative stage for better growth and development.

2.8.3 **Stalking:** Stalking of each pot was done whenever it was necessary especially in vegetative and fruit setting stages for protecting the plants from leaning.

2.9 Harvesting

Since chili plants were semi-indeterminate type which continuously grown new stems, leaves and fruits. So fruits of the plants were harvested when the fruits turned into red color. Harvesting was started from 22th March, 2022 and was continued up to 14th April 2022.

2.10 Data C~~c~~ollection and R~~r~~ecording

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

2.10.1 Air T~~t~~emperature of D~~d~~ay and N~~n~~ight (^{0}C)

The air temperature of day at 12.00 pm and night at 10.00 pm was taken by help of Thermometer at 60 DAT, 65 DAT and 70 DAT. The temperature was taken in Celsius (^{0}C).

2.10.2 Temperature of the ~~p~~Pot S~~s~~oil (^{0}C)

The temperature of the pot soil at 4.00 pm was taken by help of Thermometer at 60 DAT, 65 DAT and 70 DAT. The temperature was taken in Celsius (^{0}C).

2.10.3 Moisture Content of the ~~s~~Soil (%)

The moisture content of the soil was taken at 4.00 pm by Moisture meter at 60 DAT, 65 DAT and 70 DAT. It was taken in Percentage.

2.10.4 Light I~~i~~ntensity

Light intensity was measured by lux meter.The light intensity was recorded in lux.

2.10.5 Plant H~~h~~eight (cm)

Plant height was measured from the sample plants in centimeter using measuring tape 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, 30, 45, 60 days after transplanting and final harvesting.

2.10.6 Plant S~~s~~tem ~~d~~Diameter (cm)

Plant stem diameter was measured from the sample plants in centimeter using slide caliper. Stem diameter was recorded at 15, 30, 45, 60 days after transplanting and final harvesting**.**

2.10.7 Number of L~~l~~eaves per ~~p~~Plant

Leaf number was counted from each plant at 15, 30, 45, 60 days after transplanting and final harvesting**.**

2.10.8 Number of B~~b~~ranches per ~~p~~Plant

The total number of branches per plant was counted from each plant at 30 DAT, 45 DAT, 60 DAT and final harvesting**.**

2.10.9 SPAD Value

SPAD value of the plant was measured by using SPAD-meter (spectrophotometer) at 65 and 70 DAT.

2.10.10 Days to 1st flowering

Number of days from transplanting to 1st flowering was observed from every replication.

2.10.11 Number of F~~f~~lowers per ~~p~~Plant

Number of flowers from every chili plant was recorded at 45 DAT, 60 DAT and 75 DAT by counting.

2.10.12 Days to 1st ~~f~~Fruit S~~s~~etting

Number of days from transplanting to 1st fruiting was observed from every replication**.**

2.10.13 Number of F~~f~~ruits per ~~p~~Plant

The number of fruits per plant was counted and recorded.

2.10.14 Days to 1st fruit ripening

From transplanting date, days to 1st fruit ripening was observed from every replication.

2.10.15 Fresh W~~w~~eight and D~~d~~ry W~~w~~eight of P~~p~~lant (g)

Fresh weight of plant was calculated by measuring the weight of a plant including root and was recorded in gram (g).

Dry weight of plant was calculated by oven dry for 24 hours of the plant then measured with a weight machine and was recorded in gram (g)**.**

2.10.16 Single ~~f~~Fruit W~~w~~eight (g)

Fruits were only harvested when fully ripe. Ten fruits from each plant were randomly selected each time fruits were picked. The weight of each selected fruit was measured in grammas (g) using a weight machine and the average value was computed and displayed as the weight of a single fruit**.**

2.10.17 Single F~~f~~ruit L~~l~~ength (cm)

Fruits were picked once they had ripened. Ten fruits from each plant were randomly chosen at the time of each harvest. Using a slide caliper, the length of each chosen fruit was measured in centimeters (cm) from the fruit's neck to its bottom, and the average was determined, showing the length of a single fruit.

2.10.18 Single ~~f~~Fruit D~~d~~iameter (cm)

Fruits were picked once they had ripened. At the time of each harvest, 10 distinct fruits from each plant were chosen at random. With a slide caliper, the diameter of each chosen fruit was measured in the middle and recorded in centimeters (cm). The average value was calculated and represented as the diameter of a single fruit.

2.10.19 Fresh W~~w~~eight and ~~d~~Dry ~~w~~Weight of F~~f~~ruit ~~y~~Yield per ~~p~~Plant (g)

Fresh weight of fruit yield per plant was calculated by using formula: (Fresh fruit yield = Number of total fruit × Single fruit weight) from first to final harvest of a plant and was recorded in gram (g).
Dry weight of fruit yield per plant was calculated after oven dry for 24 hours of the yield per plant, then measured with a weight machine and was recorded in gram (g).

~~2.11 Statistical~~2.11 Statistical Analysis

All the obtained data were subjected to compiled and analyzed by Microsoft Excel Worksheet and Statistix 10 software and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance.

3. RESULTS AND DISCUSSION

The results of the experiment have been presented and discussed in this section with a view to determining the soil temperature, light intensity, soil moisture, daytime and nighttime air temperatures, and the growth, yield-contributing traits, and yield performance of chili on various building rooftop heights. Different tables and graphics display the data. The outcomes have been talked about, and pertinent interpretations are shown under the following headings:

3.1. Air temperature at D~~d~~ay and ~~n~~Night (^{0}C)

Table 1. Air temperature of day and night on rooftop of different height of buildings at different days after transplanting (DAT)

Treatments	Air Temperature of day (^{0}C)			Air Temperature of night (^{0}C)		
	60 DAT	65 DAT	70 DAT	60 DAT	65 DAT	70 DAT
T_1	30.23 d	29.7 d	30.01 d	23.21 d	23.73 d	25.36 d
T_2	31.01 c	30.41 c	32.6 c	25.7 c	26.76 c	29.58 c
T_3	31.61 b	31.12 b	33.73 b	26.75 b	27.84 b	30.49 b
T_4	32.50 a	32.99 a	34.34 a	29.04 a	28.55 a	30.28 a
CV (%)	1.24	1.06	1.00	2.00	1.83	1.22
LSD (0.05)	0.57	0.51	0.36	0.81	0.75	0.25

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

The air temperature of day and night at 60 DAT, 65 DAT and 70 DAT, highest air temperature was recorded in T_4 which was significantly higher than T_1, T_2 and T_3. The lowest air temperature of day and night was recorded in T_1 at 60 DAT, 65 DAT and 70 DAT which was compared with $T_{2,}$ T_3 and T_4. In every case, T_2 and T_3 showed significantly lower air temperature of day and night than T_4 and T_3 was significantly higher than T_2. The sequence of day and night air temperature were T_4>T_3 >T_2>T_1 (table 1). Fahim et al. (2023)[15], also found the same result and they observed that the air temperature of day and night were increased with the increased of building rooftop height.

3.2. Temperature of the P~~p~~ot ~~s~~Soil

The temperature of the pot soil at 60 DAT, 65 DAT and 70 DAT, highest temperature of the pot soil was recorded in T_4 which was significantly higher than $T_{1,}$ T_2 and T_3; the lowest temperature of the pot soil was recorded in T_1 which was compared with $T_{2,}$ T_3 and T_4, except T_3 showed statistically similar result with T_4 at 60 DAT. In every case, T_2 and T_3 showed significantly lower temperature of the pot soil than T_4 and T_3 was significantly higher than T_2.The sequence of temperature of the pot soil wasT_4>T_3 >T_2>T_1 (table 3). Fahim et al. (2023) [15] also found the same result and they observed that the temperature of pot soil was increased with the increased of building rooftop height.

Table 2. Temperature of the P~~p~~ot ~~s~~Soil of ~~c~~Chili on ~~r~~Rooftop of D~~d~~ifferent ~~h~~Height of ~~b~~Buildings at ~~d~~Different D~~d~~ays after T~~t~~ransplanting (DAT)

Treatments	Temperature of pot soil (^{0}C)		
	60 DAT	65 DAT	70 DAT
T_1	28.5 c	31.71 d	31.41 d
T_2	31.5 b	32.78 c	32.66 c
T_3	32.5 ab	33.98 b	34.01 b
T_4	33.4 a	34.98 a	35.33 a
CV (%)	2.19	1.70	1.14
LSD(0.05)	1.06	0.87	0.58

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

3.3. Moisture ~~c~~Content of the ~~p~~Pot S~~s~~oil

The moisture content of the pot soil at 60 DAT and 65 DAT, highest moisture content of the pot soil was recorded in T_1 which was significantly higher than $T_{2,}$ T_3 and T_4; the lowest moisture content of the pot soil was recorded in T_4 was compared with $T_{3,}$ T_2 and T_1. In every case, T_2 and T_3 showed significantly higher moisture content of the pot soil than T_4 and T_2 was significantly higher than T_3. At 70 DAT, T_1, T_2 and T_3 showed statistically similar result. The sequence of moisture content of the pot soil was T_4<T_3 <T_2<T_1 (T~~t~~able 4). As increase in building height of rooftop with a decrease moisture content of pot soil is associated with the study of Fahim *et al*. (2023) [15] which was moisture content of the pot soil was decreased with the increased of building rooftop height.

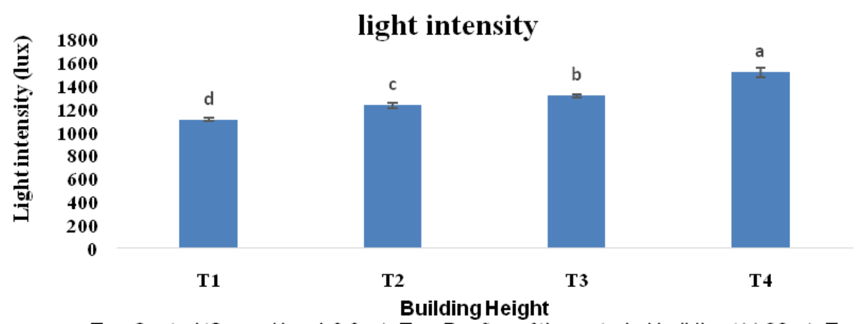
Table 3. Moisture content of the pot soil of chili on rooftop of different height of buildings at different days after transplanting (DAT)

Treatments	Moisture content of pot soil (%)		
	60 DAT	**65 DAT**	**70 DAT**
T_1	24.53 a	24.20 a	23.56 a
T_2	22.65 b	22.64 b	21.73 ab
T_3	20.59 c	20.85 c	20.11 b
T_4	18.71 d	17.98 d	19.03 c
CV (%)	2.27	2.80	2.95
LSD(0.05)	0.76	0.92	0.77

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.*

3.4. Light Intensity

Figure 1 showed that, there was statistical difference among T_1, T_2, T_3, and T_4. Highest light intensity was found in T_4 which was 1515.3 lux. Lowest light intensity was found in T_1 which was 1109.8 lux. In T_3 light intensity was significantly higher than T_2 (Ffigure 1). Light intensity showed an increasing sequence with the increasing of building height of rooftop. The sequence of light intensity was T_4>T_3 >T_2>T_1.



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) and T_4 = Rooftop of ten storied building (34.75 m)

Figure 1. Light Iintensity on rRooftop of dDifferent hHeight of bBuildings

3.5. Plant Hheight

At 15 DAT, 30 DAT, 45 DAT, 60 DAT and Final harvest, the tallest plants were found in T_1 whichwas significantly higher than T_2, T_3 and T_4; the shortest plants were observed in T_4 which was compared with T_1, T_2 and T_3. In every case, T_2 and T_3 showed significantly higher plant height than T_4 and T_2 was significantly higher than T_3 (Ttable 5). It was noted that plant height at 15 DAT, 30 DAT, 45 DAT, 60 DAT and Final harvest showed a decreasing plant height with the increase of building height of rooftop. The sequence of plant height was T_1 >T_2>T_3>T_4 (Ttable 5). As increase in building height of rooftop with an increase air temperature of day & night, temperature of pot soil but moisture content of pot soil decreased which inversely affected on plant height; high air temperature and low soil moisture occurred due to increased height of building rooftop, plant height decreased [15]. High temperature affects plant life process by affecting the stability of various proteins, membranes creates metabolic imbalance ultimately reduced plant height [19-21]. Soil moisture affected the vegetative growth of tomato and severe moisture stress (40% of PC) decreased the plant height by 24% compared to the control [22-23].

Table 4. Plant Hheight (cm) of cChili on rRooftop of Ddifferent hHeight of Bbuildings at dDifferent dDays Aafter Ttransplanting (DAT)

Treatments	Plant height (cm)

	15 DAT	30 DAT	45 DAT	60 DAT	Final harvest
T1	29.72 a	42.84 a	56.14 a	66.13 a	74.37 a
T2	26.73 b	38.23 b	51.26 b	61.10 b	63.03 b
T3	24.54 c	35.57 c	45.12 c	54.96 c	56.35 c
T4	21.45 d	29.37 d	40.45 d	48.93 d	50.09 d
CV (%)	4.46	5.10	4.92	8.22	6.11
LSD (0.05)	1.76	2.83	3.65	4.02	5.73

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

3.6. Plant stem diameter

At 15 DAT, 30 DAT, 45 DAT, 60 DAT and Final harvest, the highest plant stem diameter was found in T_1 which was significantly higher than T_2, T_3, and T_4; the lowest plant stem diameter were observed in T_4 which was compared with T_1, T_2 and T_3. In every case, T_2 and T_3 showed significantly higher plant stem diameter than T_4 and T_2 was significantly higher than T_3. An inverse relationship was noted between plant stem diameters and building height, where plant stem diameter at 15 DAT, 30 DAT, 45 DAT, 60 DAT and Final harvest showed a decreasing sequence of plant stem diameter with the increase of building height of rooftop. The sequence of plant stem diameter was $T_1 > T_2 > T_3 > T_4$ (table 6).High air temperature and low soil moisture occurred due to increased height of building rooftop, plant stem diameter decreased [15]. High temperature affects plant process like inhibits plant stem growth, development as a result decrease the plant stem diameter [24-27]. Severe moisture stress (40% of PC) decreased the plant stem diameter by 24% compared to the control [23]. Light quality affected significantly stem of pepper [28].

Treatments	Plant ~~S~~Sstem ~~d~~Diameter (cm)				
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**Final harvest**
T_1	0.35 a	0.47 a	0.66 a	0.87 a	0.93 a
T_2	0.32 b	0.44 b	0.63 b	0.82 b	0.89 b
T_3	0.29 c	0.41 c	0.59 c	0.79 c	0.84 c
T_4	0.26 d	0.38 d	0.55 d	0.73 d	0.79 d

CV (%)	4.91	2.31	2.33	1.93	0.91
LSD (0.05)	0.02	0.02	0.02	0.02	0.01

Table 5. Plant stem diameter (cm) of chili on rooftop of different height of buildings at different days after transplanting (DAT)

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

3.7. Leaf N~~n~~umber per ~~p~~Plant

Leaf number was recorded at 15 DAT, 30 DAT, 45 DAT, 60 DAT and Final harvest, the highest leaf number was found in T_1 which was significantly more than T_2, T_3, and T_4. But at 15 DAT, The leaf number at T_2, T_3 and T_4 were statistically similar but lower than T_1 and at 30 DAT, there was no statistically difference in number of leaf per plant observed between T_3 and T_4 with increasing building height. In every case, the lowest number of leaf was found in T_4. At 45 DAT, 60 DAT and Final harvest, leaf number per plant showed a reverse relationship with the increasing of building rooftop height. The sequence of leaf number per plant was T_1>T_2>T_3>T_4 (Table 7). As increase in building height of rooftop with an increase air temperature of day & night, temperature of pot soil but moisture content of pot soil decreased which adversely affected on leaf number of plant and decreased the leaf number of plant [15]. Soil moisture affected the vegetative growth of tomato and severe moisture stress (40% of PC) decreased the plant height by 24% compared to the control [22-23]. It was found that expansion growth of plant leaf is extremely sensitive to water stress [29-30] and that reduced the number of leaf per plant [31].

Table 6. Leaf N~~n~~umber of C~~c~~hili on R~~r~~ooftop of D~~d~~ifferent ~~h~~Height of ~~b~~Buildings at D~~d~~ifferent D~~d~~ays A~~a~~fter T~~t~~ransplanting (DAT)

Treatments	**Leaf number per plant**				
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**Final harvest**
T_1	14.38 a	67.69 a	168.19 a	192.94 a	212.5 a
T_2	11.06 b	63.00 b	158.06 b	182.19 b	195.27 b
T_3	10.25 bc	54.88 c	147.94 c	170.06 c	185.6 c
T_4	9.44 c	49.00 c	137.82 d	160.63 d	175.12 d

CV (%)	7.08	7.11	2.74	2.91	3.04
LSD (0.05)	1.23	2.95	6.46	7.90	9.01

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

3.8. Branch N~~n~~umber per ~~p~~Plant

At 30 DAT, the highest number of branch per plant was found at T_1 which was statistically similar with T_2 and the lowest number of branch per plant was recorded in T_4. Similar number of branch per plant recorded in T_2 and T_3 but statistically higher than T_4. At 45 DAT, at 60 DAT and at Final harvest the highest number of branch per plant was recorded at the ground level (T_1) which was and the lowest number of branch per plant was recorded in T_4. Plant number of branch per plant recorded in T_2 and T_3 which were higher than T_4 but lower than $T_{1.}$ However, there was an opposite relationship observed between number of branch per plant and building height, where number of branch per plant showed a decreased sequence of number of branch per plant with an increasing building height of rooftop. The sequence of branch number per plant was T_1>T_2>T_3>T_4 (Table 8). High air temperature and low soil moisture occurred due to increased height of building rooftop, number of branch per plant decreased [15]. High air temperature and low moisture content of pot soil occurred due to increased building rooftop height that affected the branch number of plant (Abdalla and Verkerk,1968; Abdul-Baki, 1991; Peet *etal*. 1997 and El Ahamdi and Stevens, 1979) [32-35], revealed the adverse effect of high temperature on the vegetative development in tomato plants. It was found that expansion growth of plant leaf is extremely sensitive to water stress [29-30] and that reduced the number of branch per plant [31].

Table 7. Branch N~~n~~umber of ~~c~~Chili on R~~r~~ooftop of ~~d~~Different H~~h~~eight of ~~b~~Buildings at ~~d~~Different D~~d~~ays ~~a~~After ~~t~~Transplanting (DAT)

Treatments	Branch N~~n~~umber per ~~p~~Plant			
	30 DAT	**45 DAT**	**60 DAT**	**Final harvest**
T_1	17.69 a	33.25 a	39.44 a	40.50 a
T_2	16.44 ab	31.13 b	38.19 b	38.75 b
T_3	15.06 b	27.88 c	34.00 c	35.31 c
T_4	13.31 c	26.13 d	31.38 d	32.44 d
CV (%)	5.90	3.04	1.88	2.32
LSD(0.05)	1.41	1.38	1.03	1.31

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

3.9. Chlorophyll Content of Chili Leaf

At 65 DAT and at 70 DAT, the lowest SPAD value was calculated at T_4 and the highest SPAD value was found in T_2 and T_1.There was no statistically difference among T_1, T_2, T_3 and T_4 (Table 9). The similar result was observed in the study of Fahim *et al.* (2023) [15]. At different building height of rooftop garden, chlorophyll content of leaf tissue is influenced by nutrient unavailability and environmental stresses (such as drought, salinity, cold and heat etc.), but in order to same nutrient, soil pH, and not extreme or drought condition of plant chlorophyll content was not affected significantly [36].

Formatted: Font: Italic

Table 8. SPAD Value of Chili on Rooftop of Different Height of Buildings at Different Days After Transplanting (DAT)

Treatments	SPAD Value	
	65 DAT	70 DAT
T_1	59.05	60.19
T_2	60.31	58.74
T_3	56.68	59.02
T_4	55.10	57.86
CV (%)	8.42	8.53
LSD(0.05)	NS	NS

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, LSD= Least significant difference, NS= Non-significant. 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.

3.10. Days to 1st Flowering

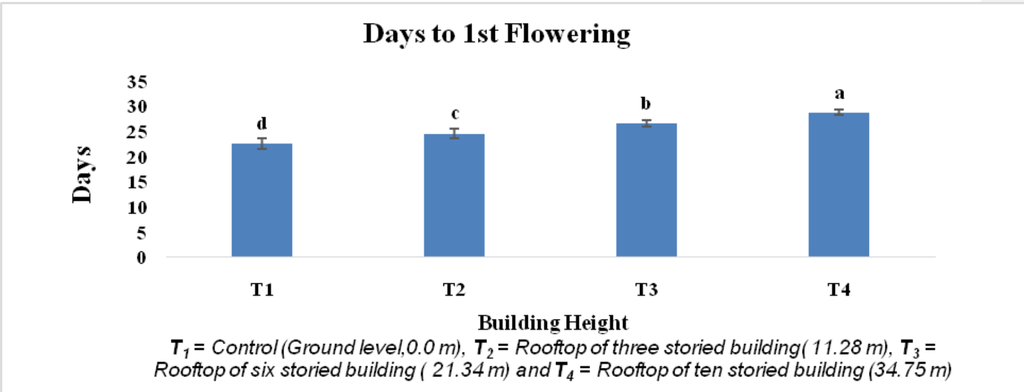


Figure 2. Days to 1st Fflowering of cChili on Rrooftop of dDifferent hHeight of bBuildings

Figure 2 showed that in terms of days to 1st flowering the highest days (29 DAT) took the 1st flowering observed in T_4 which was statistically higher than T_1, T_2 and T_3; the lowest days (23 DAT) took in T_1 which was compared with other treatments. In T_3 was statistically higher than T_2. However days to 1st flowering showed affirmative relationship with increasing building height of rooftop. The sequence of days to 1st flowering was $T_4>T_3>T_2>T_1$. High temperature affected on the reproductive development (flowering stage, fruiting stage etc.) in winter vegetables (tomato) plants and under a high temperature condition leading to late flowering [32-35]. High temperatures and low moisture condition inhibit the growth of chili, resulting late flowering [16]. High temperature delayed flowering of Pepper plant [37].

3.11. Number of Fflowers per pPlant

At 45 DAT, 60 DAT and 75 DAT, the highest number of flowers per plant was recorded in T_1 which was significantly higher than T_2, T_3 and T_4 and the lowest number of flowers per plant was recorded in T_4 which was compared with T_1, T_2 and T_3. In every case, T_2 and T_3 showed significantly higher number of flower per plant than T_4 and T_2 was significantly higher than T_3. The sequence of number of flower per plant was $T_1 > T_2 > T_3 > T_4$ (table 10). As increase in building height of rooftop with an increase air temperature of day & night, temperature of pot soil but moisture content of pot soil decreased which adversely affected on number of flower per plant; high air temperature and low soil moisture occurred due to increased height of building rooftop, number of flower per plant decreased [15]. Flower of plant abortion due to high-temperature correlated with increases in Ethylene, ACC, and ABA and decreases in IAA, Cytokinin, and polyamine ultimately reduced flower number of plant [38-39]. Heat stress responsible severe damage to spikelet, disrupts cytokinin synthesis, causes peroxide accumulation, decreases sugar levels, and damages cell construction as a result reduced flower number of pant [40-43]. Ibukun TA and Kelly TM (2020)[44], revealed that the winter Vegetables (tomato) drop flowers when exposed to several days of daytime temperature above 29°C and nighttime temperature above 21°C

Table 9. Total Nnumber cChili fFlower on Rrooftop of dDifferent hHeight of bBuildings at Ddifferent dDays aAfter tTransplanting (DAT)

Treatments	Number of Fflowers per Pplant

	45 DAT	60 DAT	75 DAT
T_1	57.13 a	42.62 a	27.88 a
T_2	52.38 b	33.87 b	22.75 b
T_3	46.56 c	27.68 c	18.46 c
T_4	41.81 d	24.18 d	15.54 d
CV (%)	3.35	3.93	5.61
LSD(0.05)	2.55	1.94	1.83

Note: Here, DAT= Days after transplanting, 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) and T_4 = Rooftop of ten storied building (34.75 m), CV= Coefficient of variation, 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.

3.12. Days to 1st Ffruiting

Figure 3 showed that in terms of days to 1st fruiting the highest days (49 DAT) took the 1st fruiting observed in T_4 which was statistically higher than T_1, T_2 and T_3; the lowest days (43 DAT) took in T_1 which was compared with other treatment. In T_3 was statistically higher than T_2, where T_1 and T_2 showed statistically same result. High temperatures and low moisture condition inhibit the growth and production of chili [16], resulting in poor fertilization and fruit set as a result late fruiting reviewed in (Snider *et al*., 2011). High ~~temperature inhibits the development of pollen grains and reduce~~temperature inhibits the development of pollen grains and reduces the pollen viability lead to late fruit setting of sweet pepper [45]. High temperature delayed fruiting of Pepper plant [37].

Formatted: Font: Italic

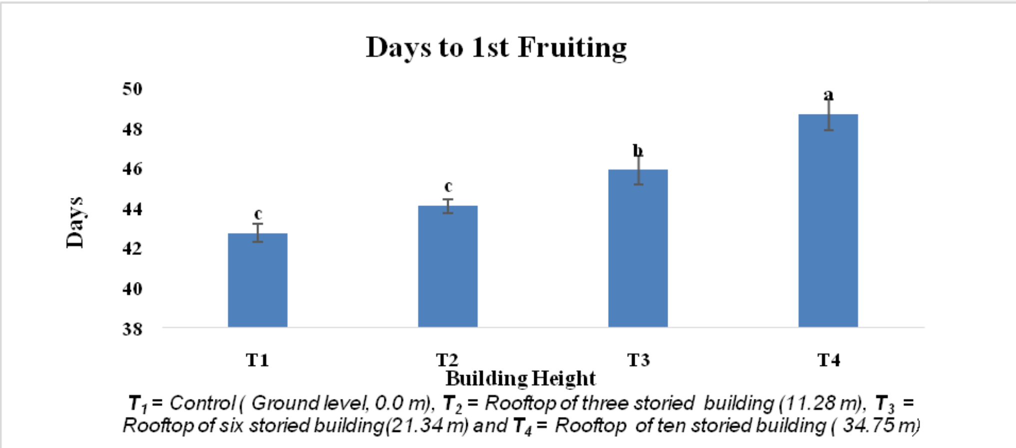
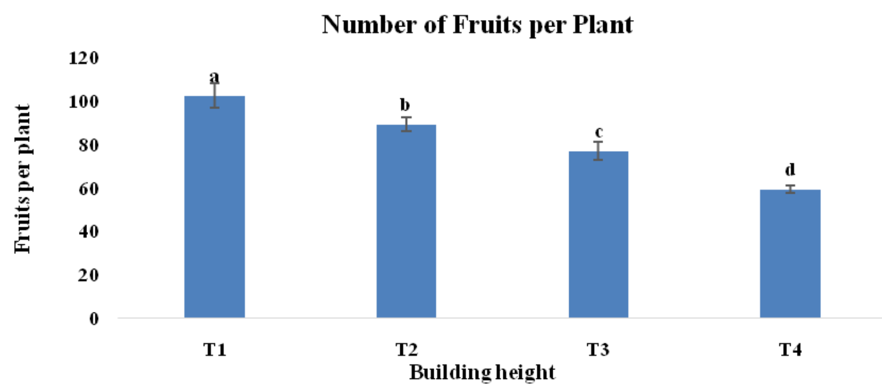


Figure 3. Days to 1st F~~f~~ruiting of C~~c~~hili on ~~r~~Rooftop of ~~d~~Different H~~h~~eight of ~~b~~Buildings

3.13. Number of F~~f~~ruits per ~~p~~Plant

The highest number of fruits (102.31) per plant was found at T_1 which was statistically higher than T_2, T_3 and T_4 and the lowest number of fruits (59.11) per plant was recorded in T_4 which was compared with other treatments. In T_2 was statistically higher than T_3 (Figure 4). However, there was an inverse relationship observed between number of fruits per plant and building height, where number of fruits per plant decreased as building height increased. The sequence of number of fruits per plant was $T_1 > T_2 > T_3 > T_4$ (F~~f~~igure 4). As increase in building height of rooftop with an increase air temperature of day & night, temperature of pot soil but moisture content of pot soil decreased which adversely affected on number of fruits per plant; high air temperature and low soil moisture occurred due to increased height of building rooftop, number of fruits per plant decreased [15]. With high temperature stress, a study reported reductions in the number of fruit in tomatoes [46-47] and rice [48]. Drought affects plant's assimilatory organs, which usually decrease in number of fruits per plant [49-52].



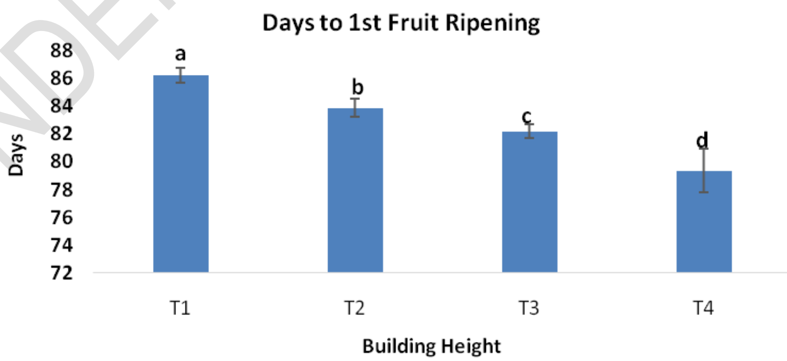
T_1 = Control, (Ground level,0.0 m), T_2 = Rooftop of three storied building (11.28 m), T_3 = Rooftop of six storied building (21.34 m) and T_4 = Rooftop of ten storied building (34.75 m)

Figure 4: Number of Ffruits per cChili pPlant on rRooftop of Ddifferent hHeight of bBuildings

3.14. Days to 1st fFruit rRipening

Figure 5 showed that 1st fruit ripening was observed in T_4 which took the least time of 79 days after transplanting and the longest time of 86 days after transplanting took to make the 1st fruit ripening observed in T_1. In T_2 and T_3, days took to 1st fruit ripening was observed 84 DAT and 82 DAT respectively. Days to 1st fruit ripening in T_1, T_2, T_3 and T_4 were statistically different from each other. The sequence of days to 1st fruit ripening was $T_1>T_2>T_3>T_4$. Fahim *et al*. (2023)f) [15] also found that the air temperature of day and night were increased and soil moisture decreased with the increased of building rooftop height, high temperature helped to reaching harvest maturity of chili pepper at 45 and 55 days after sowing in HST (Huay Si Thon, Japan) and SST (Takii Co. Ltd, Japan) with the highest full-red fruits [53]. Hot pepper taken 7.6 and 5.4 days at temperatures of 25°C and 30°C and 11.0 and 16.5 days at temperature of 15 - 20°C days from green mature fruit to ripen fruit [54].

Formatted: Font: Italic



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) and T_4= Rooftop of ten storied building (34.75 m)

Figure 5: Days to 1st fruit ripening of chili on rooftop of different height of buildings

3.15. Fresh W~~w~~eight & Dry W~~w~~eight of P~~p~~lant

The highest fresh weight (166.19 g) and dry weight (84.94 g) of plant was found in T_1 which was statistically higher than T_2, T_3 and T_4; the lowest fresh weight (96.15 g) and dry weight (30.81 g) of plant was recorded in T_4 which compared with T_1, T_2 and T_3 (figure 6). Fresh weight and dry weight of plant recorded in T_2 and T_3 which were higher than T_4 and T_2 was statistically higher than T_3. However, there was an inverse relationship observed between fresh weight & dry weight of plant and building height of rooftop, where fresh weight & dry weight of plant decreased as building height of rooftop increased. The sequence of fresh weight & dry weight of plant were $T_1 > T_2 > T_3 > T_4$ (figure 6). Hatfield *et al*. (2011) and Zhao *et al*. (2017) [55-56], reported a decrease in production, fresh weight and dry weight of some plants due to high-temperature stress. Drought affects plant's assimilatory organs, which usually decrease in size of plant resulting in lower photosynthates production, ultimately reduced fresh weight and dry weight of plant [49-52].

Formatted: Font: Italic

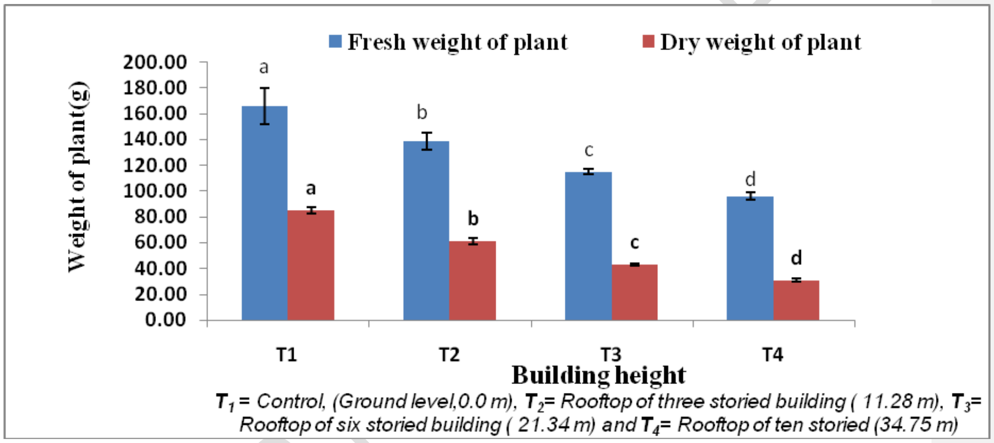


Figure 6: Fresh W~~w~~eight & D~~d~~ry W~~w~~eight of C~~c~~hili ~~p~~Plant on ~~r~~Rooftop of D~~d~~ifferent ~~h~~Height of B~~b~~uildings

3.16. Single F~~f~~ruit ~~w~~Weight

The highest single fruit weight was found inT_1 (3.48 g) which was statistically higher than T_2, T_3 and T_4; the lowest single fruit weight was recorded in T_4 (1.95 g) which compared with others treatments. Fruit weight was recorded in T_2 and T_3 which were statistically higher than T_4 and T_2 was significantly higher than T_3. However, single fruit weight showed a decreasing trend with increasing building height of rooftop. The trend of single fruit weight was $T_1 > T_2 > T_3 > T_4$ (~~f~~Figure 7). As increase in building height of rooftop with an increase air temperature of day & night, temperature of pot soil but moisture content of pot soil decreased which adversely affected on single fruits weight of plant; high air temperature and low soil moisture occurred due to increased height of building rooftop, single fruits weight of plant decreased [15]. A decrease in the fruit weight due to temperature stress was also reported by [57-59]. Liu *et al*. (2019) [22] published that winter vegetables (Tomato) yield as affected by soil moisture during fruit development stage.

Formatted: Font: Italic

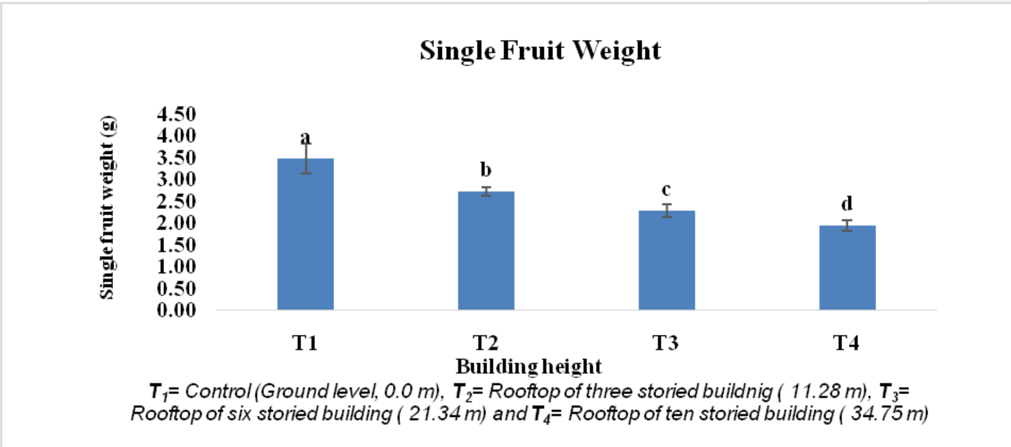


Figure 7: Single fruit weight of chili on rooftop of different height of buildings

3.17. Single F~~f~~ruit ~~l~~Length

Figure 8 showed that the highest single fruit length was found inT_1 (7.93 cm) which was statistically higher than $T_{2,}$ T_3 and T_4; the lowest single fruit weight was recorded in T_4 (6.04 cm) which compared with others treatments. Fruit length was recorded in T_2 and T_3 which were statistically higher than T_4 and T_2 was significantly higher than T_3. However, single fruit length showed a decreasing trend with increasing building height of rooftop. The trend of single fruit length was T_1 >T_2>T_3>T_4 (figure 8). High air temperature and low soil moisture occurred due to increased height of building rooftop, single fruits length of plant decreased [15]. A decrease in the fruit length due to temperature stress was also reported by [57-59].

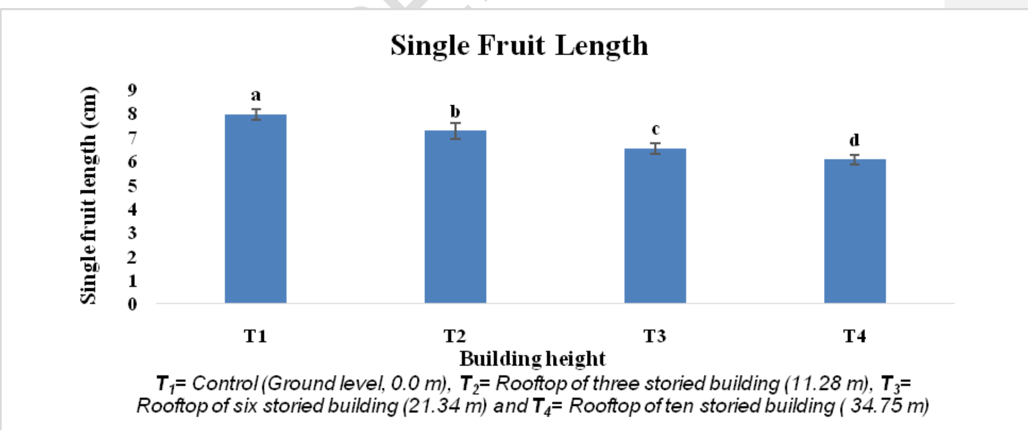
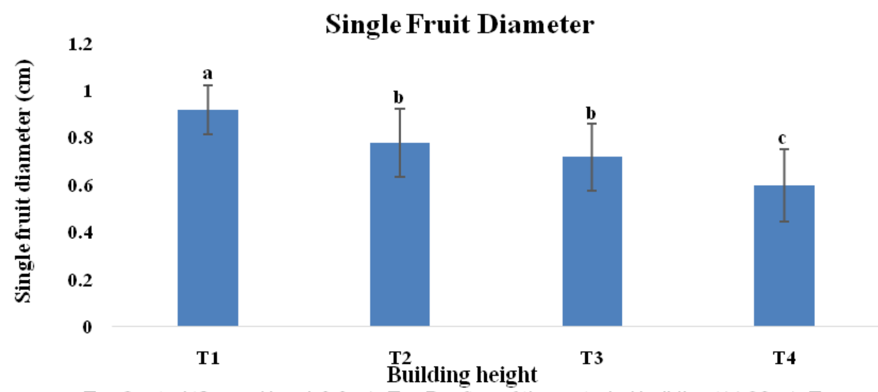


Figure 8: Single fruit length of chili on rooftop of different height of buildings

3.18. Single F~~f~~ruit ~~d~~Diameter

The highest single fruit diameter (0.91 cm) was found at T_1 which was statistically higher than $T_{2,}$ T_3 and T_4; the lowest fruit diameter (0.59 cm) was recorded in T_4 which was compared with other treatments. Fruit diameter was recorded in T_2 and T_3 which was statistically similar but higher than T_4 (Fig 9). A decrease in the fruit diameter due to temperature stress was also reported by [57-59]. High air temperature and low soil moisture occurred due to increased height of building rooftop, single fruits diameter of plant decreased [15].



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) and T_4 =Rooftop of ten storied building (34.75 m)

Figure 9 Single fFruit dDiameter of Cchili on Rrooftop of Ddifferent hHeight of bBuildings

3.19 Fresh Wweight and Ddry Wweight of yYield per pPlant

Figure 10 showed that the highest fresh weight (215.33 g) and dry weight (84.68 g) of fruit per plant was recorded inT_1 which was statistically higher than $T_{2,}$ T_3 and T_4; the lowest fresh weight (-136.88 g) and dry weight (-40.98 g) of fruit per plant was recorded in T_4 which compared with the treatments($T_{1,}$ T_2 and T_3). Fresh weight and dry weight of fruit per plant was recorded in T_2 and T_3 which were statistically higher than T_4 and T_2 was significantly higher than T_3. However, fresh weight and dry weight of fruit per plant showed a decreasing trend with increasing building height of rooftop. The trend of fresh weight and dry weight of fruit per plant was T_1 >T_2>T_3>T_4 (Ffigure 10). High temperatures during the reproductive stage will affect pollen viability, fertilization, and grain or fruit formation decreased the weight of fruits in plants and reduced the yield due to high-temperature stress of 6% in wheat, 3.2% in rice, 3.1% in soybean, and 7.4% in corn [55-56]. Lobell *et al*. (2011) [26] explained that each increase of 1°C caused a decrease in the production of up to 8.3% in corn. Drought affects plants which usually decrease yield due to less amount of assimilate available to the developing pods [49-52]. High air temperature and low soil moisture occurred due to increased height of building rooftop, fresh weight and dry weight of fruit per plant decreased [15].

Formatted: Font: Italic

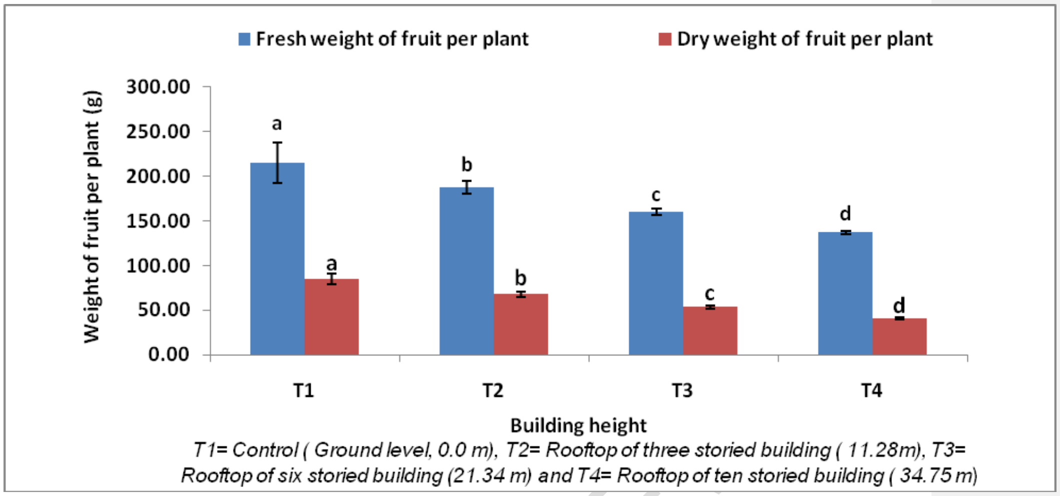


Figure 10: Fresh W~~w~~eight of F~~f~~ruit per C~~c~~hili P~~p~~lant on R~~r~~ooftop of D~~d~~ifferent ~~h~~Height of B~~b~~uildings

4. CONCLUSION

Different building height of rooftop revealed that the treatment T_1 had significantly highest moisture content of pot soil, growth, yield contributing characters and yield of chili plants which were significantly higher than all other treatments (T_2, T_3 and T_4) and T_4 showed significantly lowest result which compared with all other treatments (T_1, T_2 and T_3) but T_2 was significantly higher than T_3 and $T_{4.}$ The lowest light intensity, air temperature at day and night and temperature of pot soil was significantly found in T_1 which compared with all other treatments (T_2, T_3 and T_4) but the highest was found in T_4 which was significantly higher than all other treatments but T_2 and T_3 showed significantly lower result than T_4 and T_2 was statistically lower than T_3. The sequence of moisture content of pot soil, growth, yield contributing characters and yield of chili plants were $T_1>T_2>T_3>T_4$ but in case of light intensity, air temperature at day and at night and temperature of pot soil were $T_4>T_3>T_2>T_1$). The growth, yield, and yield-contributing characteristics of the chili plant reduced consecutively as the height of a building's rooftop gradually grew. The best production was achieved on the ground, however to boost rooftop gardening, chili (BARI Morich-3) can be grown up to the rooftop of a three-storied building.

REFERENCES

1. BBS. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistical division, Ministry of Planning, Govt. of the people's Republic of Bangladesh, Dhaka. 2014~~;p.142~~; p.142.
2. BBS. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistical division, Ministry of Planning, Govt. of the people's Republic of Bangladesh, Dhaka. 2015;p.142

3. Sultana, R., Ahmed, Z., Hossain, M. A. and Begum, B. A. Impact of green roof on human comfort level and carbon sequestration: A microclimatic and comparative assessment in Dhaka City, Bangladesh. *Int. J. Urban Climate. 2021;*38(2): 100-878.
4. Hui, S. C. M. Rooftop garden urban farming for buildings in high-density urban cities. In Proceedings of the 2011 Hainan ChinaWorldChina World Rooftop garden Conference, Hainan, China. 2011;18–21 March. 2011;pp; pp.: 1–9.
5. Tomalty, R. and Komorowski, B. Economic valuation of a rooftop food garden. Living Archit. Monit. 2010; 12: 29-33.
6. Getter, K. L.; Rowe, D. B. The role of extensive rooftop gardens in sustainable development. Hort. Science. 2006;41: 1276–1285.
7. Sajjaduzzman, Koike, M. M., Muhammed, N. An Analytical Study on Cultural and Financial Aspects of Roof Gardening in Dhaka Metropolitan City of Bangladesh. *International Journal of Agriculture & Biology*. 2005;1560– 8530/2005/07–2–184– 187/http://www.ijab.org.
8. Dubbeling, M. Urban agriculture as a climate change and disaster risk reduction strategy. UA Magazine. 2014;27; 27: 3-7..
9. Ries, A. (2014). Rooftop gardens – Drawbacks and Benefits. 2014.
10. Agarwal, Aa.,Ggupta, S.s. And aAhmed, zZ. Influence of plant densities on productivity of bellpepper (capsicum annuum) under greenhouse in high altitude cold desert of ladakh. *Acta hort*. 2007;756; 756: 309-314.
11. Ahmed, M. S. and Haque, M. A. Morphological characters and yield of five characters of chilli. *Bangladesh Hort*. 1981;8; 8(1): 13-16.
12. BBS. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistical division, Ministry of Planning, Govt. of the people's Republic of Bangladesh, Dhaka. 2017;p.142.
13. Durust, N., Sumengen, D. and Durust, Y. Ascorbic acid and element contents of Trabzon (Turkey). *J. Agril. Food Chem*. 1997;45; 45(6): 2085-87.
14. Olivier, O. J., Boelema, B. H., Daiber, C. C. and Ginsberg, L. The cultivation of green peppers. No. A2, Farming in South Africa, Horticultural Research Institute, Roodeplaat, Pretoria. pp. 1981;214-277.
15. Fahim, M.M.B.; Helal, M.G.J.; Tania S.; Habib, Z.F.B.; Husen, M.U.; Halim, A. Growth and Yield Performance of Tomato (*Lycopersicum esculentum* L.) at Different Building Heights of Rooftop Gardening. *Int. J. Environ. Clim. Change*, 2023;vol; vol. 13, no. 8, pp. 1593-1605.
16. Bhutia k. L, Khanaa VK, TombisanaMeetei NG and Nangsol Bhutia D. Effect of climate change on growth and development of chilli. *Agrotechnology*. 2018;7(2): 2168-9881.
17. Snider JL, Oosterhuis DM. How does timing, duration, and severity of heat stress influence pollen–pistil interactions in angiosperms? Plant Signal. *Behav*. 2011;6(7):930-933
18. Reeves PH, Coupland G. Response of plant development to environment: Control of flowering by daylengthday length and temperature *Curr. Opin. Plant Biol*. 2000;3; 3(1):37-42.
19. Ruelland, E.; Zachowski, A. How plants sense temperature. *Environ. Exp. Bot.* 2010;*69*, 225–232.
20. Suzuki, N.; Miller, G.; Morales, J.; Shulaev, V.; Torres, M.A.; Mittler, R. Respiratory burst oxidases: The engines of ROS signaling. *Curr. Opin. Plant Biol.*2011;14, 691–699.
21. Pagamas, P.; Nawata, E. Sensitive stages of fruit and seed development of chili pepper (*Capsicum annuum* L. var. Shishito) exposed to high-temperature stress. *Sci. Hort.* 2008;117: 21–25.
22. Liu J, Hu T, Feng P, Feng P, Wang L, Yang S. Tomato yield and water use efficiency change with various soil moisture and potassium levels during different growth stages; PLoS ONE. 2019;14: 3.
23. Sibomana IC, Aguyoh JN, Opiyo AM. Water stress affects growth and yield of container grown tomato (*Lycopersicon esculentum* mMill) plants; G.J.B.B. 2013;2(4):461-466.

24. Hasanuzzaman, M.; Nahar, K.; Fujita, M. Extreme Temperatures, Oxidative Stress and Antioxidant Defense in Plants. In Abiotic Stress—Plant Responses and Applications in Agriculture; Vahdati, K., Leslie, C., Eds.; In Tech: Rijeka, Croatia, 2013;pp. 169–205.
25. Mittler, R.; Blumwald, E. Genetic engineering for modern agriculture: Challenges and perspectives. *Ann. Rev. Plant Biol*. 2010;61, 443–462
26. Lobell DB, Bänziger, M, Magorokosho C, Vivek B. Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nat. Clim. Change*. 2011;42-45.
27. McClung, C.R.; Davis, S.J. Ambient thermometers in plants: From physiological outputs towards mechanisms of thermal sensing. *Curr. Biol*. 2010;20, 1086–1092
28. Schuerger, A.a. C.; Sschuerger, Cc.; bBrown, Cc. S.; Sstryjewski, Ee. Anatomical features of ~~pepper plants~~pepper plants (*Ccapsicum annuum* Ll.) Grown under red light- emitting diodes supplemented with blue or far-red light. *Annals of bBotany*. 1997;79: 273282.
29. Hsiao, T. C., Silk, W. K. & Jing, J. Leaf growth and water deficits: Biophysical effects. In: Control of Leaf Growth. Ed. N. R. Baker, Cambridge University Press, Cambridge. 1985;(pp. 239- 266).
30. Hsiao, T. C. & Jing, J. Leaf and root expansive growth in response to water deficits. In: Physiology of Cell Expansion during Plant Growth. Eds. D. J. Cosgrove and D. P. Knievel, American Society of Plant Physiology, Rockville, MD. 1987~~;pp~~; pp. 180-192.
31. Kirkham, M. B. Plant responses to water deficits. In: Irrigation of Agricultural Crops – Agronomy Monograph. Eds. B. A. Stewart and D. R. Nielsen. 1990;323-342.
32. Abdalla AA, Verkerk K. Growth, flowering, and fruit set of the tomato at high temperature; *Neth. J. Agr. Sci*. 1968;16: 71-76.
33. Abdul Baki. Tolerance of tomato cultivars and selected germplasm to heat stress; J. *Amer. Soc. Hort. Sci.1991;*116(6): 1113-1116.
34. Peet MM, Willits DH Gardner R. Response of ovule development and post-pollen production processes in male-sterile tomatoes to chronic, sub-acute high temperature stress; *J. Experimental Botany*. 1997;48 (306):101-111.
35. El AAB, Stevens MA. Reproductive responses of heat-tolerant tomatoes to high temperature; J. Amer. Soc. Hort. Sci. 1979;104(5):686-691.
36. Palta PJ. Instrumentation for studying vegetation canopies for remote sensing in optical and thermal infrared regions. Remote Sensing Reviews. 1990;5(1):207- 213.
37. Pereyda, G. J.M.; Clelia D.L.P,; Wilmer T.; Roberto, Z.B.; Rubein, H.A.N.; Jehu, G. N.K.; Maria, C.M. and Rene, G. High Temperature and Elevated CO_2 Modify Phenology and Growth in Pepper Plants*Agronomy*. 2022;*12*(8), 1836.
38. Goren R. Anatomical, physiological, and hormonal aspects of abscission in citrus, *Hortic. Rev*. 2010~~;15~~; 15: 145-182.
39. Liu Y, Gu D, Wu W, Wen X, Liao Y. The relationship between polyamines and hormones in the regulation of wheat grain filling. PLoS ONE. 2013;8(10): e78196. doi:10.1371/journal.pone.0078196.
40. Das S, Krishnan P, Nayak M, Ramakrishnan B. High temperature stress effects on pollens of rice (*Oryza sativa* L.) genotypes. *Environ. Exp. Bot*. 2014~~;101~~; 101: 36-46. DOI: doi.org/10.1016/j.envexpbot.2014;01.004.
41. Rieu I, Twell D, Firon N. Pollen development at high temperature: From acclimation to collapse. *Plant Physiol*. 2017~~;173~~; 173(4): 1967-1976.
42. Zhang C, Li G, Chen T, Feng B, Fu W, Yan J, Islam MR, Jin Q, Tao L, Fu G. Heat stress induces spikelet sterility in rice at anthesis through inhibition of pollen tube elongation interfering with auxin homeostasis in pollinated pistils. Rice. 2018;11(14): 1-12.
43. Wu W, Shah F, Duncan RW, Ma BL. Grain yield, root growth habit, and lodging of eight oilseed rape genotypes in response to a short period of heat stress during flowering. *Agric. For. Meteorol*. 2020;287(15): 107969.
44. Ibukun TA, Kelly TM. Increasing air temperatures and its effects on growth and productivity of tomato in South Florida. *Journal of Plants*. 2020;9(9):1245.

45. Erickson, A. N., and Markhart, A. H. "Flower Production, Fruit Set and Physiology of Bell Pepper during Elevated Temperature and Vapor Pressure Deficit." *J. Amer. Soc. Hort. Sci*. 2001;126; 126 (6): 697-702.
46. Meco V, Egea I, Albaladejo I, Campos JF, Morales B, Ortiz-Atienza A, Capel C, Angosto T, Bolarin MC, Flores FB. Identification and characterization of the tomato parthenocarpic mutant high fruit set under stress (hfs) exhibiting high productivity under heat and salt stress. *Ann Appl Biol*.2019;1–1
47. Panthee DR, Kressin JP, Piotrowski A. Heritability of flower number and fruit set under heat stress in tomato. *Hortic. Sci*. 2018;53(9): 1294-1299.
48. Yaliang W, Lei W, Jianxia Z, Shengbo H, Huizhe C, Xiang J, Zhang Y, Zeng Y, Shi Q, Zhu D, Zhang Y. Research progress on heat stress of rice at flowering stage. *Rice Sci*. 2019;26; 26(1): 1-10.
49. Kaiser, W. M. Effects of water deficit on photosynthetic capacity. *Physiological Plantarum*. 1987;71,142-149.
50. Chaves, M. M. Effects of water deficits on carbon assimilation. *J. Expt. Bot*. 1991;42, 1-16.
51. Larcher, W. Physiological plant ecology: ecophysiology and stress physiology of functional groups. New York Berlin Heidelberg: Springer-Verlag. 1995; 506.
52. Chaves, M. M., Pereira, J.S., Maroco, M.L., Rodrigues, C.P.P., Ricardo, M.L., Osório, I., Carvalho, T., Faria & Pinheiro,C. How plants cope with stress in the field: photosynthesis and growth. *Ann. Bot*. 2002; 89, 907916.
53. Pagamas, P.; Nawata, E. Sensitive stages of fruit and seed development of chili pepper (*Capsicum annuum* L. var. Shishito) exposed to high-temperature stress. *Sci. Hort.* 2007;117: 21–25.
54. Seo-Young Oh and Seok Chan Koh. Fruit Development and Quality of Hot Pepper (*Capsicum annuum* L.) under Various Temperature Regimes. Horticultural science and technology. 2019;37(3):313-321.
55. Hatfield *et al*.; J.L. Hatfield, K.J. Boote, B.A. Kimball, L.H. Ziska, R.C. Izaurralde, D. Ort, A.M. Thomson, D.W. Wolfe Climate impacts on agriculture: implications for crop production. *Agron. J*. 2011;103,pp. 351-370
56. Zhao C, Liu B, Piao S, Wang X, Lobell DB, Huang Y, Huang M, Yao Y, Bassu S, Ciais P, Durand JL, Elliott J, Ewert F, Janssens IA, Li T, Lin E, Liu Q, Martre P, Müller C, Peng S, Peñuelas J, Ruane AC, Wallach D, Wang T, Wu D, Liu Z, Zhu Y, Zhu Z, Asseng S. Temperature increase reduces global yields of major crops in four independent estimates. *Proc. Natl. Acad. Sci*. 2017;114; 114 (35): 9326-9331. doi.org/10.1073/pnas.1701762114.
57. Thuy TC, Kenji M. Effect of high temperature on fruit productivity and seed-set of sweet pepper (*Capsicum annuum* L.) in the field condition. *J. Agric. Sci. Technol*. 2015;5; 5: 515-520. doi: 10.17265/2161-6256/2015.12.010.
58. Kumar D, Tembhurne GD, Vikas BV, Kulkarni V, Beldhadi RV, Shekar GC, Kisan B. Screening for temperature tolerant genotypes and genetic parameter studies in chili (*Capsicum annuum* L.). *Int. J. Curr. Microbiol. Appl. Sci*. 2020;9; 9(1): 534-541. doi.org/10.20546/ijcmas.2020.901.059.
59. Kaur N, Dhaliwal MS, Singh P. Evaluation of hot pepper (*Capsicum annuum* L) genotypes for heat tolerance during the reproductive phase. *Int. J. Bio-Resour. Stress Manag*. 2016;7(1): 126-129.