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Effect of temperature and varieties on performance of tomato in Bangladesh

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ABSTRACT

An experiment was conducted to find out the effect of temperature and varieties on performance of tomato in Bangladesh. The experiment comprised of ten varieties of tomato namely, BARI tomato 2 (Roton), BARI tomato 3, BARI tomato 9 (Lalima), BARI tomato 14, Surakkha, BARI hybrid tomato 5, BARI hybrid tomato 6, Mintoo tomato (Lal Teer Seed Ltd.), Tidy tomato (Metal Seed Ltd.) and Roma VF (ACI Seed Ltd) and three temperature conditions viz., normal temperature (10-20°C), medium temperature (21-25°C) and high temperature (26-35°C). All of the treatments were arranged into the pots. There were altogether 30 treatment combinations with three replications. The experiment was laid out in a Split-plot Design. Both different temperature conditions, varieties of tomato. Almost all the parameters responded negatively at high temperature. The highest plant height (86.43 cm), maximum number of fruit per cluster (4.08), number of fruit per plant (33.90), length and (5.18 cm) diameter of fruit (5.05 cm), individual fruit weight (67.67 g), fruit weight per plant (2.25 kg), yield per hactere (62.86 t/ha) and dry weight of fruit (4.23%) were recorded from normal temperature. Different tomato varieties showed significant variations to different temperature conditions. The highest chlorophyll-a (1.03 mg/gfw), chlorophyll-b (0.29 mg/gfw) total chlorophyll (1.29 mg/gfw) in leaves, fruit weight per plant (2.06 kg) and yield per hactere (57.06 t/ha) were recorded from the variety BARI tomato 2. Moreover, BARI tomato 2 also performed better in respect of yield (1.78 kg /plant and 49.39 t/ha) and chlorophyll content in leaves when grown under high temperature condition. So, variety BARI tomato 2 seems promising for better yield of tomato during summer season of Bangladesh.

INTRODUCTION

Tomato is a universally known vegetable and is one of the widest grown vegetables in the world and leads all other vegetables in total volume of production.

Total production continues to rise all over the world and scenario of tomato in Bangladesh is not different from the other parts of the world. It occupies an area of 1,88,000 acres of land with annual production of about 1,67,000 metric tons in Bangladesh (BBS, 2005). Although the total cultivated area and production of tomato in our country have been increased gradually over the last few years, the productivity is still very low (6.46 t/ha) compared to the average yield (26.29t/ha) of the world (FAO, 2002).

Tomato production in Bangladesh is constrained by many factors of which seasonality (grow only winter) and multiple diseases are main problems. Although tomato can grow under a wide range of climatic conditions, they are extremely sensitive to hot and wet growing condition, limiting its adaptation in humid tropics, the weather which prevails in the summer -rainy season of Bangladesh. Fruit setting in tomato is reportedly interrupted at temperature above 26/20º C day/night, respectively and is often completely arrested above 38/27º C day/night (Ei-Ahmadi and Stevens, 1979a; Kuo et al., 1979 and Stevens and Rudich, 1978). For optimum fruit setting, tomato requires a night temperature of 15 to 20ºC (Charles and Harris.1972; Schaible, 1962; Verkerk, 1955; Osborne and Went, 1953; Went, 1944 & 1945). The optimum condition for fruit setting in Bangladesh is only available in winter season (November to February).

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Due to favorable growing conditions there are many varieties in winter season, in Bangladesh developed locally or introduced from abroad. But limited efforts have been employed so far to overcome the high temperature barrier preventing fruit setting in summer-rainy (hot-humid) season. The Asian Vegetable Research and Development Center (AVRDC) began its tomato improvement program in 1972 with the general goal of developing tomatoes for the tropics. The program emphasized at the outset development of breeding lines which are heat tolerant and resistant to bacterial wilt, as these are absolutely essential for tropical adaptation (Opena, 1985; Opena et at., 1987a and Villareal and Lai, 1979). Very recently, Bangladesh Agricultural Research Institute (BARI) has strengthened the program for year-round tomato variety development and already succeeded to develop some heat tolerant open pollinated (OP) tomato varieties (Anon, 1998). But most of those varieties need hormone application for good or economic setting of fruits.

So, it is easily understandable that for heat tolerant tomato variety development, different tomato varieties should be screened under particular situation. In Bangladesh, a few works have been done in this regard to develop heat tolerant tomato variety. Therefore, the proposed study has been undertaken to generate information in this respect under hot condition of Bangladesh. The generated information might be helpful for heat tolerant variety development in Bangladesh.

MATERIALS AND METHODS

Planting materials

Ten tomato varieties were used in this experiment. The seeds of tomato varieties were collected from the market of Patuakhali and Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

Experimental treatments

The experiment consists of two factors. Factor A: Different levels of temperature conditions

There were three levels of temperature conditions: T1 = Normal temperature 10-20°C (16.1°C), T2 = Medium temperature 21-25°C (21.66°C) and T3 = High temperature 26-35°C (30°C). Factor B: Tomato Varieties: Ten varieties of tomato were selected for the researech work and they are: V1 = BARI tomato 2 (Roton), V2 = BARI tomato 3, V3 = BARI tomato 9 (Lalima), V4 = BARI tomato 14, V5 =Surakha, V6 = BARI hybrid tomato 5, V7 = BARI hybrid tomato 6, V8 = Minto (Lalteer seed Ltd.), V9 = Tidy (Metal seed Ltd.), V10 = Roma VF (ACI Seed Ltd.).

Experimental design

The experiment was laid out in a Split-Plot Design replicating each treatment three times with two-factors. Each replication consists of 30 (10 × 3) pots. Thus the total number of pots were (30 × 3) = 90.

Location

Geographically the experimental area is located at 20°20′′ N latitude and 90°20′′ E longitude. It belongs to the Agro Ecological Zones 13 (AEZ-13) named Ganges Tidal Flood Plain soils of clay loam in texture (UNDP and FAO, 1988) with pH 8.0. The elevation of soil is 1.5 m above the sea level (FAO, 1988). The soil is silty loam in texture.

Weather and climate

The experimental field was under subtropical climates characterized by high temperature, high humidity, heavy precipitation during April to October and relatively low temperature and low rainfall with high humidity from October to February. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the study period.

Tomato cultivation

Raising of seedlings

Ten varieties of tomato seedlings were raised in ten distinct seed beds at the “Horticultural Nursery and Germplasm Centre”, at PSTU under special cares. The size of unit seedbed was 3 m × 1 m.

Well decomposed cowdung was applied to the prepared seedbeds at the rate of 10 t/ha. Ten grams (10 g) tomato seeds of each variety were sown in each seedbed on 20 October 2009. After sowing, the seeds were covered with finished light soil. After germination seedlings were shaded with bamboo mat (*chatai*) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Seedlings were also covered by net to protect them from vector of virus. Irrigation, weeding and mulching were given whenever necessary for better growth of seedlings.

Pot preparation

At first soil was collected for the pot experiment. Then it was well pulverized and dried under the sun. There were 90 plastic pots which were filled with 10 kg soils and 100 g well decomposed cowdung in each pot. Three pores were made at the bottom side of each plastic pot and then the gravels and straw were placed over the pore to drain out excess water easily. During the final soil preparation the soil was treated with Cynocarb-3 G @ 10 kg/ha to protect young seedlings against the attack of cutworm, grasshopper and mole cricket.

Application of manures and fertilizers

Manures and fertilizers were applied according to the recommendation guide BARI, 2004. Well decomposed cowdung, Urea, TSP and MoP were used. Total amount of well decomposed cowdung, TSP and 50% of MoP were applied during the final pot preparation. The rest 50% of MoP was applied 20 days after transplanting in ring method. Urea was applied in two installments; first one was applied 7 days after transplanting and second one was applied 20 days after transplanting.

Transplanting, maintaining temperatures, intercultural operations, irrigation and weeding, gap filling, pruning and staking were performed following standard procedure described elsewhere.

For Plant protection against pests Ripcord (BASF Bangladesh Limited) was applied @ 2 ml/L at 7. At the early vegetative stage precautionary measure against disease infections especially late blight of tomato was taken by spraying Sidazim @ 2 g/L especially during foggy weather. At the reproductive stage, Mencozev was also applied @ 2 g/L against late blight disease of tomato.

Harvesting and recording data

Plant height, number of branches per plant, number of leaves per plant, length of largest leaves, breadth of largest leaves were recorded.
For yield and yield components the number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, first flowering days, first fruiting days, first ripening days, length of fruit, diameter of fruit, individual fruit weight, fruit weight per plant, yield per hectare, length of root, diameter of root (cm) were measured. Physiological parameters include dry weight of fruit, dry weight of leaf, dry weight of root were measured

Biochemical parameters include determination of chlorophyll content in leaves were determined according to the procedure described by Arnon (1949).

Statistical analyses

The collected data representing growth, yield contributing characteristics and yield were analyzed statistically to obtain the level of significance following the analysis of variance (ANOVA) technique by "F" variance test. The mean differences were compared by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984) using the statistical computer package program, MSTAT-C (Russell, 1986).

RESULTS AND DISCUSSION

Growth parameters

Plant height

Effect of different temperature conditions

Effect of different temperature conditions was highly significant at different days after transplanting (DAT) in respect of plant height. It was observed that plant height was increased sharply from 30 to 45 DAT, then gradually increases up to 75 DAT. Later on the increasing

rate slowed down up to 105 DAT. It was found that the reduction rate of plant height was highest at high temperature. At 105 DAT, the longest plant height (86.43 cm) was recorded from the normal temperature and the shortest plant height (81.53 cm) was recorded from the high temperature. This might be due to high day/night temperature. As a result, transpiration and respiration rate was high due to which plants of high temperature phase water stress condition in spite of providing same irrigation facilities.

Effect of varieties

Plant height of different tomato varieties was significantly influenced at different days after transplanting. All varieties increased sharply from 30 to 45 DAT. Later on the increasing rate slowed down up to 105 DAT. Among the different varieties, Tidy performed comparatively best while the variety BARI tomato 9 performed the lowest up to 105 DAT. At 105 DAT, the highest plant height (104.4 cm) was recorded from the variety Tidy. However, the lowest plant height (76.56 cm) was recorded from the variety BARI tomato 9. This might be due to the varietal performance which may vary from variety to variety.

Number of branches per plant

Effect of different temperature conditions

Different temperature conditions had significant effect on the number of branches per plant at different days after transplanting. The number of branch per plant increased sharply from 30 DAT to 45 DAT, but drastically falls down from 45 to 60 DAT. This might be due to pruning operation. From 60 to 105 DAT, the number of branches increased again but the increasing trend was slow. The highest number of branches per plant (11.03) was recorded from medium temperature, whereas the lowest number of branch (9.37) was recorded from normal temperature.

Effect of varieties

Different varieties significantly influenced the number of branch per plant of tomato. Similar kind of result was found among the varieties of tomato as found in different temperature conditions at different DAT. Among the trends, variety BARI tomato 3 performed comparatively best, while variety Mintoo performed the lowest trend up to 105 DAT. This might be due to different levels of tolerance by the cultivars. At 105 DAT, the variety BARI tomato 3 produced the maximum branch per plant (12.78), whereas the variety Mintoo produced the minimum number of branches per plant (9.00).

Number of leaves per plant

Effect of different temperature conditions

At different DAT effect of different temperature conditions was found significant in respect of this parameter. A similar trend was also found as number of branch per plant affected by the different temperature conditions. Number of leaves per plant increased sharply from 30 to 45 DAT but drastically falls down from 45 to 60 DAT. Later on number of leaves increased again but the increasing rate slowed down up to 105 DAT. So far, the highest number of leaves per plant (24.30) were recorded from medium temperature at 105 DAT, while the lowest leaves number (21.40) were recorded from normal temperature.

Effect of varieties

There was found significant effect on the number of leaves per plant of tomato by different tomato varieties at different DAT. Number of leaves of all varieties increased sharply from 30 to 45 DAT but drastically falls down from 45 to 60 DAT due to pruning operation. From 60 to 75 DAT all varieties again increased sharply but from 75 to 105 DAT the increasing rate slowed down. Among the varieties, it was found that variety Tidy performed comparatively best, while variety BARI tomato 9 performed lowest up to 105 DAT. At 105 DAT, variety Tidy produced the maximum number of leaves per plant (25.78), whereas the minimum number of leaves per plant (22.00) were produced by the variety BARI tomato 9. This might be due to the varietal performance.

Length of largest leaves

Effect of different temperature conditions

Different temperature conditions had significant effect on the length of largest leaves of tomato at different days after transplanting. It was observed that the length of largest leaves was sharply increased from 30 to 45 DAT and slows down up to 105 DAT (Fig. 7). Different trends indicated that length of largest leaves was highly affected by high temperature. This might be due to water stress at high temperature. However, the highest length of largest leaves (38.00 cm) was recorded from normal temperature, which was statistically similar with medium temperature, (37.43 cm) and the lowest length of largest leaves (36.63 cm) was recorded from high temperature at 105 DAT.

Effect of varieties

Different varieties significantly influenced the length of largest leaves of tomato at different DAT. Sharp increase was found from 30 to 45 DAT and as the days after transplanting increased, the increasing trends reduced up to 105 DAT. Different trends indicated that variety BARI tomato 2 comparatively performed best. The highest length of largest leaves (38.33 cm) was recorded from the variety BARI tomato 2, while the lowest length of largest leaf (36.56 cm) was recorded from the variety BARI tomato 9 at 105 DAT. This might be due to the varietal performance to produce largest length of leaf.

Breadth of largest leaves

Effect of different temperature conditions

Different temperature conditions had highly significant effect on the breadth of largest leaves of tomato at different days after transplanting. Different trend indicated that the breadth of largest leaves was sharply increased from 30 to 45 DAT, then the increasing rate slows down up to 105 DAT. The highest performance was recorded from normal temperature, while the lowest performance was recorded from the high temperature in respect of this parameter up to 105 DAT (Fig. 9). The highest breadth of largest leaves (33.17 cm) was observed in normal temperature which was statistically similar with medium temperature (32.63 cm), while the lowest breadth of largest leaves (30.77 cm) was observed in the high temperature at 105 DAT.

Effect of varieties

There was found significant effect on the breadth of largest leaves of tomato in this respect. The breadth of largest leaves sharply increased from 30 to 60 DAT and after that slowed down up to 105 DAT. (Fig. 10). Among the varieties, it was observed that variety BARI tomato 2 performed comparatively best and variety BARI tomato 9 showed the lowest trend up to 105 DAT. This might be due to the varietal level of tolerance which may vary from variety to variety. However, the highest breadth of largest leaves (34.89 cm) was observed in the variety BARI tomato 2, while the lowest breadth of largest leaves (30.78 cm) was observed in the variety BARI tomato 9 at 105 DAT.

Yield and yield components

Number of cluster per plant

Effect of different temperature conditions

Different temperature conditions had significant effect on the number of cluster per plant of tomato. The maximum number of cluster per plant (9.07) was obtained from the medium temperature. The minimum cluster number per plant (8.40) was obtained from normal temperature. This might be due to more branching at medium temperature.

Effect of varieties

Significant effect on cluster number per plant was found by different varieties of tomato. The variety Mintoo produced the highest number of cluster per plant (10.89) and variety BARI tomato 2 produced the second highest number of cluster per plant (9.33). The lowest number of cluster per plant (5.89) was recorded from the variety BARI tomato 14 (Table 1).

Number of flower per cluster

Main effect of different temperature conditions

Different temperature conditions showed significant influence on the number of flower per cluster. Flower number decreased at normal temperature. The lowest flower number per cluster (5.44) was counted from normal temperature while, the highest flower number per cluster (7.05) was recorded from medium temperature (Table 1). This might be due to more number of cluster per plant at medium temperature.

Effect of varieties

Significant effect on the number of flower per plant was found by different varieties of tomato. The variety Roma VF produced the maximum flower number per cluster (6.58) whereas the variety Tidy produced the minimum number of flower (5.43) per cluster (Table 1). This might be due to the varietal performance to produce number of flower per cluster.

Number of fruits per cluster

Main effect of different temperature conditions

Different temperature conditions significantly influenced the number of fruit per cluster. The lowest number of fruit per cluster (3.43) was obtained from high temperature and the highest number of fruit per cluster (4.08) was obtained from normal temperature (Table 1). Went (1945) reported that temperatures between 30 to 40°C cause reduced fruit set which support the present finding.

Table 1
Main effect of different temperature conditions and varieties on the yield and yield components of tomato plant.

Treatments	Number of cluster per plant	Number of flower per cluster	Number of fruit per cluster	Number of fruit per plant	First flowering days	First fruiting days	First ripening days
Different temperature conditions							
T_1	8.40 b	5.44 b	4.08 a	33.90 a	33.93 c	52.77 c	94.17 a
T_2	9.07 a	7.05a	3.62 b	31.50 b	38.00 b	54.37 b	89.60 b
T_3	8.90 a	5.60 b	3.43 b	30.30 c	38.87 a	55.63 a	88.30 c
Level of significance	**	*	**	**	**	**	**
CV %	14.68	8.42	12.48	4.31	1.43	1.02	1.00
LSD (0.05)	0.32	1.01	0.27	1.13	0.37	0.54	0.75
Varieties							
V_1	9.33 b	5.54 de	3.87 ab	35.33 ab	37.33 d	53.11 e	92.44 a
V_2	9.44 b	5.75 cde	3.47 bc	32.00 d	37.67 cd	58.44 a	91.56 ab
V_3	9.00 bc	5.59 de	3.32 c	29.44 e	38.00 bc	57.56 b	90.56 cd
V_4	5.89 d	6.00 bcd	3.83 ab	22.33 f	37.56 cd	50.33 f	89.78 d
V_5	7.89 c	6.46 ab	4.28 a	33.44 c	38.67 a	54.89 c	91.22 bc
V_6	7.89 c	6.31 ab	4.08 a	31.89 d	38.00 bc	55.22 c	90.89 bc
V_7	10.22 ab	6.17 abc	3.30 c	33.33 c	35.78 f	53.78 d	91.22 bc
V_8	10.89 a	6.44 ab	3.17 c	34.11 bc	36.67 e	50.33 f	86.78 e
V_9	9.56 b	5.43 e	3.79 ab	36.00 a	38.00 bc	50.78 f	90.78 bc
V_{10}	7.78 c	6.58 a	4.03 a	31.11 d	38.33 ab	58.11 a	91.67 ab
Level of significance	**	**	**	**	**	**	**
CV %	14.68	8.42	12.48	4.31	1.43	1.02	1.00
LSD (0.05)	1.22	0.48	0.44	1.30	0.51	0.52	0.86

Effect of varieties

Variety significantly influenced the number of fruit per cluster. The variety Surakha gave the highest number of fruit per cluster (4.28), which was statistically identical to variety BARI hybrid tomato 5 (4.03), Roma VF (4.08) and BARI tomato 2 (3.87), whereas the variety Mintoo produced the lowest number of fruits per cluster (3.17) (Table 1). This might be due to the reason that variety Roma VF produced highest number of flower per cluster.

Number of fruits per plant

Effect of different temperature conditions

Different temperature conditions had significant effect on the number of fruit per plant. The normal temperature produced the maximum number of fruit per plant (33.90) and the high temperature produced the minimum number of fruit per plant (30.30). Anon. (1975) reported that high temperatures reduce fruit set of tomato.

Effect of varieties

Significant effect was observed by different varieties in this regard. The variety Tidy tomato produced the maximum number of fruit per plant (36.00), while the minimum number of fruit per plant (22.33) was recorded from the variety BARI tomato 14 (Table 1). This might be due to the varietal performance which may vary from variety to variety.

First flowering days

Effect of different temperature conditions

Different temperature conditions had significant effect on first flowering days of tomato. The high temperature took longest period for the first flowering (38.87 days), while the normal temperature produced the earliest flowering (33.93 days) from Table 1. Iwahori (1965) reported that high day temperature delays in flowering which support the present finding.

Effect of varieties

Different varieties had significant effect on first flowering days of tomato plant. The tabulated results showed that the shortest days required for first flowering (35.78 days) was observed from the variety BARI hybrid tomato 6 and secondly Mintoo (36.67days), whereas the longest period required for first flowering (38.67 days) was observed from the variety Surakha which was statistically similar to Roma VF (38.33 days) (Table 1). This might be due to the varietal performance which may vary from variety to variety.

First fruiting days

Effect of different temperature conditions

It was found that different temperature conditions had also significant effect on first fruiting days. The normal temperature took lowest period to produce fruit (52.77 days). Whereas, high temperature took longest period (55.63 days) for the first fruiting (Table 1). Iwahori (1965) reported that high day temperature delays in flowering can lead to delays in fruit production which supports the present finding.

Effect of varieties

The shortest days (50.33) required for first fruiting was observed in the variety Mintoo, and BARI tomato 14 which was statistically similar to variety Tidy (50.78), whereas the longest period (58.11days) required for first fruiting was observed in the variety Roma VF (Table 1). It might be due to variety Roma VF gave delayed flowering, which ultimately gave delayed fruiting. Dinar et al., (1983) found that decreased assimilate and carbon export at high temperature was greater in heat sensitive Roma VF which delay in flowering and fruiting.

First ripening days

Effect of different temperature conditions

Different temperature conditions had significant effect on first ripening days of fruits of tomato. The normal temperature took longest period for the first ripening (94.17 days). As the temperature rises, the days required for ripening reduced. The

high temperature caused the earliest ripening (88.30 days) (Table 1).

Effect of varieties

First ripening days of fruit significantly influenced by different varieties of tomato. The result showed that the shortest days (86.78) required for first ripening of fruit was observed in the variety Mintoo tomato, whereas the longest period required for first ripening of fruit (92.44 days) was observed in the variety BARI tomato 2 (Table 1). Earliest flowering and fruiting may caused earliest ripening of Mintoo tomato variety.

Length of fruit

Effect of different temperature conditions

Different temperature conditions had significant influence on length of fruit of tomato. The highest length of fruit (5.18 cm) was found at normal temperature and the lowest length of fruit (4.52 cm) was obtained from high temperature which was statistically similar to medium temperature (4.70 cm) (Table 2). Sawhney and Polowick (1985) reported that low temperature fruits were larger than high temperature fruits which supports the present result.

Effect of varieties

Different varieties significantly influenced the length of tomato fruits. The maximum length of fruit (5.42 cm) was recorded from the variety Roma VF, which was similar to BARI tomato 9 (5.41 cm) and BARI tomato 14 (5.27 cm), while the minimum length of fruit (3.81 cm) was recorded from the variety Mintoo tomato (Table 2). Maximum length of fruit might be due to delay in ripening of Roma VF which accumulated more food materials in the fruits. Minimum length of fruit might be due to early ripening of variety Mintoo which accumulated less food materials in the fruits. This variation of length might be also due to the variation in size and shape of fruit of different varieties. Rylski (1973) also reported that temperature determines the fruit size in various crops.

Diameter of fruit

Effect of different temperature conditions

Different temperature conditions had significant influence on diameter of fruit of tomato. The maximum diameter of fruit (5.05 cm) was measured from the normal temperature and the minimum fruit diameter (4.41 cm) was recorded from the high temperature (Table 2). Saito and Ito (1967) reported that high temperature reduced the tomato fruit size which support the present result.

Effect of varieties

Diameter of fruit was significantly influenced by different variety. The maximum diameter of fruit (5.46 cm) was recorded from the variety BARI tomato 14, while the variety Tidy performed the lowest diameter (4.23 cm) of fruit (Table 2). The variety Tidy gave ripening fruit at earliest time, for this reason accumulation of reserved food materiel was low in the fruit. On the other hand, length of fruit was also higher in BARI tomato 14. It might be also due to varietal variation. Rylski (1973) reported that temperature determines the fruit size in various crops.

Individual fruit weight

Effect of different temperature conditions

Different temperature conditions had significant effect on Individual fruit weight. The highest individual fruit weight (67.67 g) was found in the treatment normal temperature, However, The lowest individual fruit weight (53.87 g) was found in the treatment high temperature (Table 2). Sawhney and Polowick (1985) reported that low-temperature fruits were larger then high temperature fruits.

Effect of varieties

Different variety had significant effect on individual fruit weight of tomato. It was found from table 2 that the variety BARI 14 produced maximum individual fruit weight (85.33 g), whereas the variety Mintoo produced the minimum individual fruit weight (49.33 g). Such results might be due to highest fruit length and diameter produced by BARI 14 and lowest fruit length and diameter produced by variety Mintoo.

Length of root

Effect of different temperature conditions

Different temperature conditions had significant influence on the length of root of tomato plant. The longest length of root (44.67 cm) was obtained from normal temperature while, the shortest length of root (40.90 cm) was recorded from high temperature (Table 2). Went (1944) reported that at low temperatures the rate of carbohydrate translocation influences growth of stems, root and fruit.

Table 2
Main effect of different temperature conditions and varieties on the yield and yield yield components of tomato plant.

Treatments	Length of fruit (cm)	Diameter of fruit (cm)	Individual fruit weight (g)	Length of root (cm)	Diameter of root (cm)
Different temperature conditions					
T_1	5.18 a	5.05 a	67.67 a	44.67 a	1.24 a
T_2	4.70 b	4.64 b	58.83 b	41.53 b	1.23 a
T_3	4.52 b	4.41 c	53.87 c	40.90 c	1.14 b
Level of significance	**	**	**	**	*
CV %	6.23	5.83	0.78	0.69	9.09
LSD (0.05)	0.22	0.13	0.83	0.29	0.05
Varieties					
V_1	4.59 c	4.71 bc	58.00 e	44.56 bc	1.30 a
V_2	4.62 c	4.93 b	62.00 d	41.78 e	1.40 a
V_3	5.41 a	4.57 c	65.00 b	34.11 h	1.17 b
V_4	5.27 a	5.46 a	85.33 a	44.78 b	1.19 b
V_5	4.61 c	4.57 c	52.67 i	44.33 c	1.18 b
V_6	4.62 c	4.67 bc	54.89 g	43.67 d	1.18 b
V_7	4.61 c	4.70 bc	55.89 f	36.44 g	1.19 b
V_8	3.81d	4.66 bc	54.11 h	51.67 a	1.18 b
V_9	4.99 b	4.23 d	49.33 j	41.11 f	1.08 b
V_{10}	5.42 a	4.83 cd	64.00 c	41.22 f	1.17 b
Level of significance	**	**	**	**	**
CV %	6.23	5.83	0.78	0.69	9.09
LSD (0.05)	0.28	0.26	0.44	0.28	0.10

Effect of varieties

Diameter of root

Effect of different temperature conditions

Similar result was also observed in respect of root diameter with the increase of temperature. The minimum root diameter (1.14 cm) was recorded from high temperature. The result showed that the maximum diameter of root (1.24 cm) was measured from the normal temperature (Table 2). Went (1944) reported that at low temperatures the rate of carbohydrate translocation influences growth of stems, root and fruit which support the present result.

Effect of varieties

Diameter of root was significantly influenced by different variety. The maximum diameter of root (1.30 cm) was recorded from the variety BARI tomato 2 and BARI tomato 3 (1.40) while the variety Tidy performed the lowest diameter (1.08 cm) and it was identical to rest of the varieties (Table 2).

Fruit weight per plant

Effect of different temperature conditions

Different temperature condition influenced the individual fruit weight of tomato significantly. The result showed that the highest fruit weight per plant (2.25 kg) produced at normal temperature. Whereas, the lowest fruit weight per plant (1.61 kg) produced at high temperature (Figure 1). Sugiyama et al., (1966) reported that day temperatures below 30°C favour fruit set and yield which supports directly the present study result.

Effect of varieties

Different varieties significantly influenced the fruit weight per plant. The variety BARI tomato 2 produced the maximum fruit weight per plant (2.06 kg) and the minimum fruit weight per plant (1.76 kg) was recorded from the variety BARI hybrid tomato 6 which was statistically similar (1.77 kg) to variety BARI hybrid tomato 5 (Figure 2). Number of fruit per plant and individual fruit weight might be the key factor for such result.

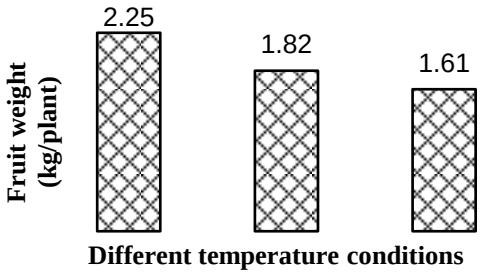

Figure1
Main effect of different temperature conditions on the fruit weight per plant of tomato.

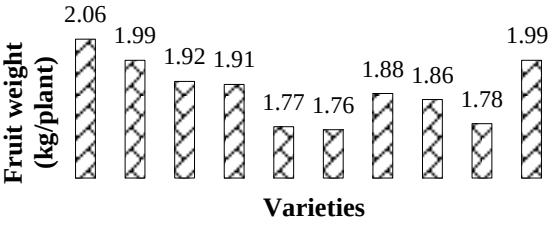

Figure 2
Main effect of varieties on the fruit weight per plant of tomato (The vertical bar represents LSD at 0.05 levels).

Yield per hectare

Effect of different temperature conditions

Analysis of variance showed that there was significant effect on yield per hectare of tomato plant by different temperature conditions. Normal temperature condition produced the maximum yield (62.86 t/ha), whereas high temperature produced the minimum (44.51 t/ha) yield (Figure 3). Stevens and Rudich (1978) found that fruit set was one of the key components of final yield in tomato that was greatly affected by adverse conditions, particularly temperatures. This was an agreement to support the present study work.

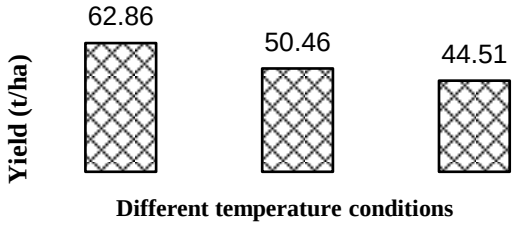

Figure 3
Main effect of different temperature conditions on the yield per hactere of tomato (The vertical bar represents LSD at 0.05 levels)

Effect of varieties

It was found that different varieties had highly significant effect on the yield of tomato plant. The variety BARI tomato 2 gave the highest yield (57.06 t/ha), while the variety BARI hybrid tomato 5 (49.10 t/ha) and BARI hybrid tomato 5 (49.09 t/ha) gave the lowest yield (Figure 4). Number of fruit per plant and individual fruit weight produced the highest yield per plant, which ultimately might help to produce highest yield per hectare to variety BARI tomato 2.

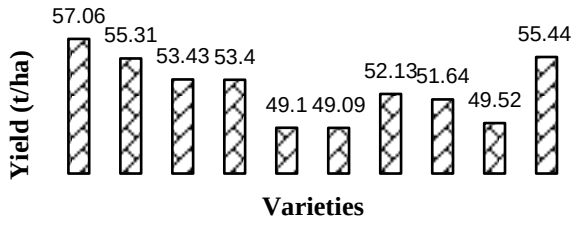

Figure 4
Main effect of varieties on the yield per hactere of tomato (The vertical bar represents LSD at 0.05 levels).

Physiological parameters

Dry weight of fruit

Effect of different temperature conditions

Different temperature conditions had significant effect on dry weight of fruit. It was found from the result that normal temperature produced the maximum dry weight of fruit (4.23%). The minimum dry weight of fruit (3.29%) was obtained from high temperature (Table 3). Hewitt and Curtis (1948) observed the depletion of carbohydrates due to increased respiration at high temperatures to produce dry matter.

Effect of varieties

Dry weight of fruit was significantly influenced by different varieties of tomato. The maximum dry weight of fruit (4.72%) was found from the variety Surakkha which was statistically similar to variety BARI tomato 14 (4.53%), while the minimum dry weight of fruit (3.08%) was found from the variety BARI tomato 3 (Table 3).

Dry weight of leaf

Effect of different temperature conditions

Different temperature conditions had significant effect on dry weight of leaf. The result showed that the maximum dry weight of leaf (16.01%) was found from the normal temperature and the minimum dry weight of leaf (12.79%) was measured from the high temperature (Table 3). Hewitt and Curtis (1948) observed the loss of dry matter and carbohydrates from leaves by respiration and translocation at high temperature which support the result.

Effect of varieties

Significant variation of dry weight of leaf was observed among the tomato varieties. The variety BARI tomato 14 performed maximum dry weight of leaf (16.75%), while the lowest dry weight (13.10%) of leaf was measured from variety Tidy and secondly from variety BARI tomato 2 (13.18%) (Table 3).

Dry weight of root

Effect of different temperature conditions

Different temperature conditions had significant effect on dry weight of root. The result showed that the maximum root dry weight (42.81%) was found from the normal temperature and the minimum dry weight of root (35.78%) was measured from the high temperature treatment (Table 3).

Effect of varieties

Significant variation of root dry weight per plant was also observed among the tomato varieties. The variety Mintoo performed maximum root dry weight (45.00%), while the variety BARI tomato 2 performed the minimum root dry weight (35.20%) per plant (Table 3).

Biochemical parameters

Chlorophyll-a content in leaves

Effect of different temperature conditions

Different temperature conditions had significant effect on the chlorophyll-a content in leaves of tomato plants. The highest chlorophyll-a in leaves (0.94 mg/gfw) was obtained from medium temperature and the lowest chlorophyll-a in leaves (0.87 mg/gfw) was obtained from high temperature (Table 3).

Effect of varieties

Main effect of different varieties was also found significant in respect of this parameter. The variety BARI tomato 2 produced the highest chlorophyll-a in leaves (1.00 mg/gfw), whereas the lowest chlorophyll-a in leaves (0.85 mg/gfw) was measured from the variety BARI hybrid tomato 5 and Surakkha (Table 3).

Chlorophyll-b content in leaves

Effect of different temperature conditions

Different temperature conditions had significant effect in respect of chlorophyll-b content in leaves.

The highest chlorophyll-b (0.26 mg/gfw) was obtained from the medium temperature, whereas the lowest chlorophyll-b (0.20 mg/gfw) was obtained from the high temperature (Table 3).

Table 3
Main effect of different temperature conditions and varieties on the physiological and biochemical characteristics of tomato plant

Treatments	Dry weight of fruit (%)	Dry weight of leaves (%)	Dry weight of root (%)	ChlorophyllI a (mg g-1 fw)	Chlorophyll b (mg g-1 fw)	Total Chlorophyll (mg g-1 fw)
Different temperature conditions						
T_1	4.23 a	16.01 a	42.81 a	0.92 b	0.24 b	1.08 b
T_2	3.76 b	14.51 b	40.67 b	0.94 a	0.26 a	1.13 a
T_3	3.29 c	12.79 c	35.78 c	0.87 c	0.20 c	1.04 c
Level of significance	**	**	**	**	**	**
CV %	7.31	5.15	2.26	2.63	4.74	1.83
LSD (0.05)	0.14	1.39	1.38	0.02	0.01	0.01
Varieties						
V_1	3.56 de	13.18 e	35.20 f	1.00 a	0.25 a	1.23 a
V_2	3.08 f	13.34 de	40.10 d	0.90 cd	0.22 c	1.08 de
V_3	4.11 c	15.66 bc	37.29 e	0.90 cd	0.21 d	1.083 d
V_4	4.53 ab	16.75 a	35.48 f	0.97 b	0.25 a	1.15 b
V_5	4.72 a	15.87 b	39.39 d	0.85 e	0.23 c	0.99 g
V_6	3.32 ef	15.05 c	42.26 bc	0.85 e	0.21 d	1.01 f
V_7	3.17 f	13.80 de	41.84 c	0.90 cd	0.22 c	1.06 e
V_8	4.36 bc	14.08 d	45.00 a	0.89 d	0.22 c	1.07 de
V_9	3.59 d	13.10 e	38.00 e	0.92 cd	0.24 b	1.08 de
V_{10}	3.16 f	13.50 de	43.01 b	0.93 c	0.25 a	1.11 c
Level of significance	**	**	**	**	**	**
CV %	7.31	5.15	2.26	2.63	4.74	1.83
LSD (0.05)	0.26	0.70	0.85	0.03	0.01	0.02

Effect of varieties

Varieties had highly significant effect on chlorophyll-b content in leaves of tomato plant. The variety BARI tomato 2 and Roma VF produced the highest chlorophyll-b in leaves (0.25 mg/gfw), whereas the lowest chlorophyll-b in leaves (0.21 mg/gfw) was measured from the variety BARI hybrid tomato 5 (Table 3).

Total chlorophyll content in leaves

Effect of different temperature conditions

Different temperature conditions had significant effect total chlorophyll content in leaves. The treatment medium temperature produced the highest total chlorophyll in leaves (1.13 mg/gfw), whereas high temperature produced the lowest (1.04 mg/gfw) total chlorophyll content in leaves (Table 3). It might be due to presence of polythene tunnel which hinders presence of direct sunlight to produce chlorophyll in leaves.

Effect of varieties

Total chlorophyll content in leaves significantly influenced by the different varieties of tomato.

The variety BARI tomato 2 produced the highest total chlorophyll in leaves (1.23 mg/gfw), whereas the variety BARI hybrid tomato 5 produced the lowest (0.99 mg/gfw) total chlorophyll in leaves. (Table 3).

CONCLUSIONS

Different temperature conditions, varieties and also the combination influenced significantly almost all the characters studied from tomato plant. Different temperature conditions significantly influenced the growth, yield and yield contributing characteristics of tomato plants. Different tomato varieties also showed significant tolerances to different temperature conditions.

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